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NOVEMBER 1955

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Collective Review

FIFTY YEARS OF NEUROSURGERY, 1905-1955

JOHN E. SCARFF, M.D., F.A.C.S., New York, New York

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THE GENERAL SURGEON

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- Cerebral abscesses
- Epilepsy
- Surgery of the spine
- Trigeminal neuralgia

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  - Pinealoma
  - Colloid cyst of the third ventricle
- Intracranial tumors—Intramedullary group
  - Tumors arising above tentorium

From the Department of Neurological Surgery, College of Physicians and Surgeons, Columbia University, New York.

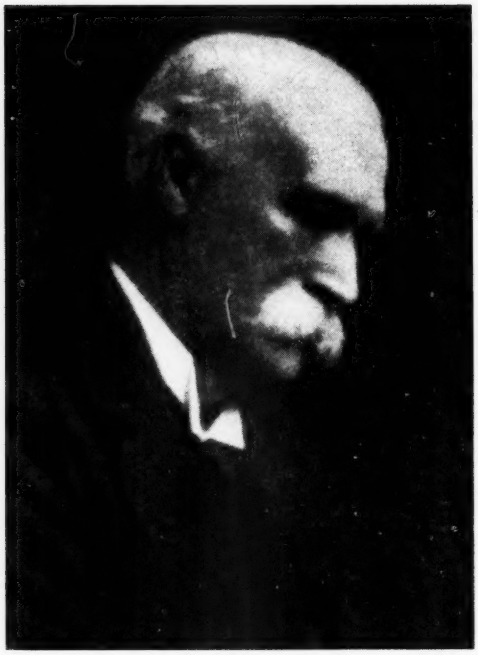

FIG. 1. Sir William Macewen.

Glioblastoma multiforme
Astrocytoma
Oligodendroglioma
Tumors arising below tentorium
Medulloblastoma
Astrocytoma
Hemangioblastoma
Ependymoma
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THE NEUROSURGICAL TEAM

PART I. NEUROSURGERY, 1905

THE GENERAL SURGEON

Origins of Neurosurgery

TWO FAR-REACHING DISCOVERIES paved the way for the development of neurologic surgery. The first of these, namely, the discovery by Lister (277), in 1867, of the cause of wound suppuration and a means of preventing it through antiseptic measures, benefited the entire domain of human surgery. The second, namely, the discovery of focal representation of function in the brain by Fritsch and Hitzig (199), in 1870, provided the special stimulus which set in motion the evolution of neurologic surgery. By 1873 Ferrier (157) had mapped out in detail the motor points on the brains of a great number of barnyard and laboratory animals and in 1874 repeated this on the brain of the monkey (158, 159, 160). In that same year Bartholow (21), then Professor of Medicine at Cincinnati, demonstrated the focal representation of function in the human brain by plunging electrodes through a defect in the skull caused by an eroding neoplasm and, by changing the position of his electrodes, was able to demonstrate several focal responses in the contralateral extremities of his patient. The fact that the experiment caused the death of the patient by meningitis at most only hastened an inevitable end, but it elevated that "unknown" person to a unique niche in medical history.

Within 5 years (1879) of this first crude demonstration of the localization of function within

the human brain, William Macewen (293) (FIG. 1) of Glasgow located and removed from the left frontal fossa of a patient a large meningioma "en plaque" with a full return to health of the patient. Two years later (297), in 1891, he localized and drained a large intracerebral abscess, although unfortunately the patient never recovered. In June, 1883 and again in December, 1883 (295) he successfully localized and evacuated two chronic subdural hematomas with good recovery of the patient in each instance. In December, 1885 Macewen (296) reported 2 cases in which he had performed laminectomy for the relief of paraplegia due to compression of the spinal cord, with practically complete recovery of function; in August, 1888 (297) he reported 21 craniotomies and 6 laminectomies.

Brain Tumors

In May, 1884 Durante (145,146) of Rome had removed an intracranial meningioma the size of an apple from a patient who made a perfect recovery. In November, 1884 Godlee (26) of London, assisted by Bennett and Ferrier, successfully removed a glioma the size of a walnut from the motor strip of a man, but unfortunately 4 days later suppuration set in and was followed by cerebral herniation, meningitis, and death. In February, 1886 Hirschfelder and Morse (233, 448) of San Francisco partially removed a glioma from the central area of the left cerebrum, but lost their patient on the seventh postoperative day from meningitis.

In the meantime Horsley (241) (FIG. 2) had been active and in October, 1886 reported 3 successful craniotomies performed that year for (1) the removal (May 25, 1886) of a large cortical scar, (2) the removal (June 29, 1886) of a tuberculoma, and (3) excision (July 13, 1886) of an epileptogenic focus determined by electrical stimulation. In April, 1887 (242) he reported 7 additional craniotomies, all of which had been carried out in 1886, of which 4 were for the relief of epilepsy, 2 for the removal of brain tumors, and 1 was for the evacuation of a cerebral cyst. Nine of these patients recovered promptly from the operation and were benefited; one of the patients with brain tumor died of operative shock, but the full report by Horsley of the successful total removal (December, 1886) of the other brain tumor, weighing 4.5 ounces, aroused widespread interest and did much to further the cause of neurologic surgery.

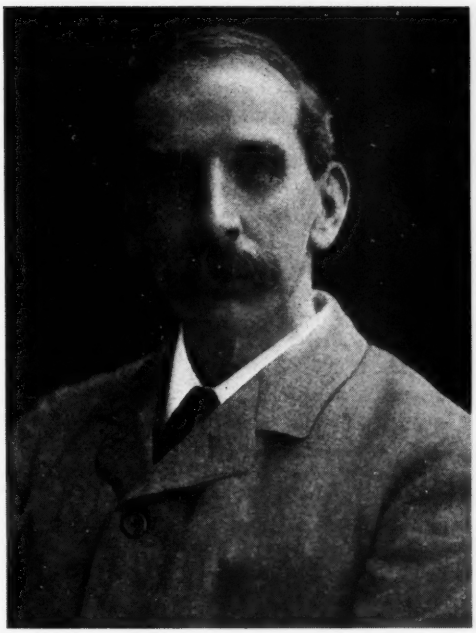

FIG. 2. Sir Victor Horsley.

In March, 1887 Weir (30) of New York totally removed a huge meningioma which arose from the upper surface of the tentorium; the patient was in fair condition at the end of the operation but succumbed to shock 7 hours later. However, in November, 1887 Weir (495) did successfully remove a subcortical tumor the size of a walnut from the face and arm area of a patient's left hemisphere with good recovery and survival of the patient for 4 months before recurrence of the tumor caused his death. In December, 1887 Keen (258) successfully removed from the left cerebrum a meningioma weighing 49 grains. The patient recovered from the operation and survived for many years.

By the end of 1888 there had been reported 14 operations for brain tumor (Table I). Eleven of the patients had *cerebral* tumors; of these, all immediately survived operation, but one died of shock 7 hours after operation, another died of wound suppuration and meningitis on the seventh postoperative day, and one died of suppuration and meningitis on the twenty-eighth postoperative day. The mortality for these first 11 cerebral tumors reported is therefore slightly less than 30 per cent. The 3 patients with *cerebellar*

TABLE I.—FIRST 14 REPORTED OPERATIONS FOR THE REMOVAL OF BRAIN TUMOR

Surgeon	*Tumor site*	*Tumor pathology*	*Date of operation*	*Reference in literature*	*Result*
1. Macewen, William	Frontal left	?Meningioma	June 21, 1879	294, 296	Recovery—lived for 8 years; self-supporting
2. Macewen, William	Rt. cerebrum	Gumma	1883	296, 298	Recovery—performs housework
3. Durante, F.	L. cerebrum	?Meningioma	May, 1884	145, 146	Complete recovery—working 3 years later
4. Godlee, R. J.	Rt. cerebrum	Subcortical glioma	Nov. 25, 1884	26	Suppuration of wound; death on twenty-eighth P.O. day
5. Hirschfelder, J.	Rt. cerebrum	Glioma	Feb., 1886	233, 448	Suppuration; death on seventh P.O. day
6. Horsley, Victor	Rt. cerebrum	Tuberculoma	May 25, 1886	241, 242	Recovery—no fits during 6-month follow-up
7. Horsley, Victor	Rt. cerebrum	Glioma "4.5 oz."	Sept. 23, 1886	241, 242	Recovery—improvement for 3 months; death after 6 months
8. Horsley, Victor	Rt. cerebrum	?Glioma	Dec. 7, 1886	241, 242	Recovery—no recurrence during 4 month observation
9. Horsley, Victor	Rt. cerebellum	Tuberculoma "7 drachms"	Dec. 17, 1886	241, 242	Death—19 hours P.O.
10. May, B.	Rt. cerebellum	Glioma, hard "size walnut"	Oct. 10, 1886	312	Death—after a few hours
11. Suckling, C. W.	L. cerebellum	Cystic ?glioma	Apr. 25, 1887	465	Death—after 48 hours
12. Weir, Robert	Rt. cerebrum	Meningioma arising from tentorium	Mar. 9, 1887	30	Death—7 hours P.O.
13. Weir, Robert	L. cerebrum	Subcortical hard glioma	Nov. 17, 1887	495	Recovery—survival for 5 months
14. Keen, W. W.	L. cerebrum	Meningioma	Dec. 15, 1887	259	Recovery—survival for 7 years

tumor included in this list all died from shock after 3, 7, and 48 hours, respectively, an operative mortality of 100 per cent for the cerebellar tumors. The over-all mortality for both the cerebral and cerebellar tumors was 48 per cent.

In 1893, five years later, Starr (448) listed 84 operations for brain tumor which he had collected from the literature; in 32 the tumor had not been found at operation and all of the patients died; of the 52 in whom the tumor had been found, 15 died, and the result in one patient was unknown; 36 patients survived. The operative mortality for the cerebral tumors in this group was approximately 50 per cent and for the cerebellar tumors approximately 80 per cent; the over-all mortality was about 60 per cent. It is interesting that 44 surgeons had operated upon these 52 patients and that only 4 of them had operated upon more than a single patient—Macewen (5), Horsley (5), Weir (2), and McBurney (2). Starr in 1896 (450) and again in 1903 (451) wrote comprehensive surveys of all brain tumors reported in the literature up to that time.

A series of remarkable "progress reports" on the results of operation for the removal of cerebral tumors was submitted by Knapp (267) of Boston in 1889, in 1891, in 1899, and in 1905; his last report compares the number of tumors found, the number removed, and the results of the operations at the time each of the four reports was made:

	1889	*1891*	*1899*	*1905*	*Total*
Cases in which tumor was removed	18	28	265	160	471
Cases in which tumor was not removed	6	20	224	107	357
Percentage of failures to find tumors	22	26	30	27	
Percentage of failures to remove tumors	25	41	46	40	
Percentage of operative mortality	46	42	32	29	
Percentage of patients not benefited	58	54	58	48	

Knapp himself concluded his report with the rather gloomy observation that, whereas the number of operations performed had increased from 24 in 1889 to 267 in 1905, there had been "little, if any, real gain in the percentage of tumors actually found and removed."

The reason, of course, that there was so little improvement in the results of operations performed for the removal of brain tumors during these years between 1889 and 1905 was that the operations were all done by general surgeons who had no training or experience in brain surgery and no special interest in it; they simply felt compelled "to do a brain case" and report it in order "to keep up with Jones." One unhappy experience usually sufficed to rid the general surgeon of his compulsion to be a "brain surgeon," and only the rare individuals let

themselves in for another similar experience. A survey of the Surgeon General's Index Catalogue for the years 1886 to 1896 revealed the amazing fact that during the 10 year period immediately following the successful removal of a brain tumor by Horsley, more than 500 different general surgeons reported operations performed upon the brain! The fact that in the next 10 years from 1896 to 1906 the number of surgeons reporting cases had fallen to less than 80 reflected discouragement and a beginning return to sanity. During the 10 years from 1906 to 1916 the number of surgeons reporting operations on the brain was, by comparison, a mere handful; all of them were men who were beginning to concentrate all or the greater part of their energy to this special field of surgery.

Cerebral Abscesses

The results of the surgical treatment of cerebral abscess in the early days of neurosurgery were on the whole quite disheartening. Macewen's first patient (297) operated upon in 1881 had died a few hours after operation. In 1891 Agnew (448) collected from the literature reports of 18 abscesses of the brain which had been operated upon, all of which cases had terminated fatally. In *Sajou's Annual*, since defunct, from 1888 to 1892, inclusive, there were, according to Starr (448), records of 55 patients with abscess of the brain who had been operated upon. Of these, 34 recovered and 21 died (66 per cent mortality).

In 1906 Starr (452) collected from the literature reports on 511 patients with abscess of the brain who had been operated upon, of whom 248 recovered (48 per cent). This incidence of recovery has remained practically constant from that time until the recent introduction of antibiotics (235).

In the very midst, however, of almost uniformly discouraging reports on the results of treatment of intracranial abscesses, Macewen (298) of Glasgow, in 1893, published one of the most remarkable books ever written on a neurosurgical subject entitled, "Pyogenic Infective Diseases of the Brain and Spinal Cord" (FIG. 9-a). In this book Macewen gives his results in 94 patients with infective intracranial lesions personally treated by him, there being 64 detailed case reports. Among the 94 patients there were 5 with extradural abscesses who were operated upon with 5 recoveries (100%) and 25 with brain abscesses of whom 19 were operated upon and 18 were cured (95%). No one since Macewen's time has been able to approach his results even remotely.

Epilepsy

The surgical treatment of focal epilepsy had a peculiar appeal for the early neurosurgeons, which is readily understood when it is recalled that it was the localization of focal motor points in the brain by Fritsch and Hitzig (199) in 1870 and Ferrier (157) in 1873 which set in motion the whole field of neurologic surgery. Thus, in Horsley's very first report of a neurosurgical operation in 1887, 3 of 10 patients had been operated upon by him for the relief of focal convulsions (242). Similarly, in Keen's first report of 3 cases of intracranial surgery, published in 1888 (258), the first and second patients were operated upon for the relief of focal epilepsy. In one a gross cortical scar was found and removed from the vicinity of the motor area; in the other no gross scar was visible when the brain was exposed, but the thumb and finger areas were identified by electrical stimulation and a sizable block of cortex was excised. In the same year Deaver (278) reported a case of focal epilepsy in which treatment by trephining and excision of the motor centers was successful; again the cortex appeared to be normal, the appropriate motor centers were identified by electrical stimulation, and a sizable piece of cortex was excised[1].

In his book "Brain Surgery" (FIG. 9d), published in 1893, Starr (448) devotes one chapter to "Trephining for Epilepsy." In this he states that "this operation has been done over three hundred times within the past five years with very few deaths." He cites a report by Laurient in 1891 of 102 collected cases in which operation was done for treatment of epilepsy, with 54 of the patients being cured, 20 benefited, 17 not benefited, 2 made worse, and 7 dead; and a report published by Agnew in 1891 of 57 additional cases which he had collected from the literature with 4 patients reported cured, 32 benefited, 9 not benefited, 4 with unknown results, and 4 dead.

Starr himself collected and reported case histories of an additional 42 patients operated upon

[1]Here again the constantly recurring and easily recognizable pattern of behavior of these early surgeons is seen: although both Keen's and Deaver's operations were beautifully conceived and executed quite early in their surgical careers, we find not a single additional case of this nature reported by either surgeon.

Case	*Date of Operation*	*Sex & Age*	*Duration of Disease*	*Nature of Disease*	*Segment or Segments, seat of Initial Spasm*	*Operation*	*Healing of Wound*	*Result*	*Surgeon and Physician*	*Place of Publication*
O.H.	19 x. 1886	M. 10	4 yrs.	Severe generalised fits, principally nocturnal, uncontrollable and destructive	Left angle of mouth (frequently bilateral)	Exposure of facial area in R hemisphere. Determination by excitation. Excision of focus	Immediate union	Diminution of fits. Perfect mental recovery. Education complete vii, 1890	Horsley Ferrier	JOURNAL, 23, iv, 1887.
W. B.	30 v. 1888	M. 20	7 yrs.	Severe generalised fits. Morose and despondent	Left fingers and wrist	Exposure of upper limb area in R hemisphere. Determination by excitation. Excision of focus	Immediate union	Diminution in number and severity of attacks. Improvement in mental condition	Keen	*International Jour. of Medical Science, xi,* 1888.
C. R.	4 x. 1888	M. 27	18 yrs.	Severe right-sided fits, becoming generalised	Thumb	Exploration of Left hemisphere. Determination of thumb focus. Excision of same	Immediate union, delayed a little by accumulation of wound secretion	Arrest of the epilepsy. Report ceased three weeks after operation	Nancrede	*Medical News,* 24, xi, 1888, p. 586
J. G.	12 vi. 1888	M. 35	14 yrs.	Severe generalised fits	Left fingers and wrist	Exposure of upper limb area in R hemisphere. Determination by excitation. Excision of focus	Primary union delayed	Arrest of epilepsy	Deaver Lloyd	*International Jour. of Medical Science,* xi, 1888, p. 477.
R. L.	23 i. 1890	M. 39	17 yrs.	(*a*) Severe generalised fits. (*b*) Attacks of *petit mal*	Left shoulder (when first seen)	Exploration of cortex, slight evidence of fibroid change in arachnoid. Determination of shoulder and other upper limb foci by excitation. Excision of shoulder focus	Immediate union	Marked mental improvement. Temporary arrest of the severe fits. Return of epilepsy as before three months later	Crichton-Browne Horsley	Unpublished.
G. C.	16 i. 1890	M. 41	25 yrs.	Generalised fits. No *petit mal*	Fingers and wrist	Exploration. Exposure of genu of fissure of Rolando. Dura little adherent. Cortex yellowish. Removal of fingers and wrist foci	Immediate union	Complete arrest of the epilepsy, vii, 1890	Horsley Jackson	Unpublished.

FIG. 3. Tabulation of operations performed by Horsley prior to 1900 for the relief of focal epilepsy. Note particularly a center column in the tabulation revealing the radical excision of epileptogenic foci carried out by Horsley.

for epilepsy, 13 of whom had been personally studied by him and operated upon at his direction by various of his surgical colleagues. The results in Starr's total group of 42 patients were reported as 13 cured, 11 benefited, 15 not benefited, and 3 dead. The over-all operative mortality for the entire 42 patients was 7 per cent.

Starr's 13 personal patients were operated upon by McBurney (9), Hartley (1), Weir (1), Briddon (1), and Poore (1), with only one death

(Weir's case). It is interesting in this connection that McBurney, who is best known in the medical profession for his classical incision for appendectomy, has here performed without a death 9 craniotomies with removal of epileptogenic foci; probably no other surgeon of his period had such an extensive personal operative experience for the relief of epilepsy.

One of the startling features about all the early surgery for epilepsy is the abandon with which the early general surgeons—Horsley, Keen, McBurney, and Deaver—excised great areas of the brain from the primary motor cortex, a procedure which today would cause deep concern to the neurosurgeon. An outstanding example of this is the fact that in the very first case which Horsley reported (242) he removed a scar from the leg area and in a total of 4 of his first 10 cases he removed portions of the motor cortex, and in his comprehensive statistical review of all his neurosurgical operations published in 1890 (243) he reports no less than 6 such ablations (FIG. 3). Famous, of course, is his total ablation of the pre-Rolandic convolution for relief of athetosis reported in the Linacre Lecture of 1909 (245).

The words with which Starr concluded his chapter on "Trephining for Epilepsy" make interesting reading:

> The question then arises, Shall we continue to trephine any cases of traumatic or localized epilepsy? Judging by general results which are unfavorable, we should be inclined to stop. But when it is taken into consideration that in no case is it possible without an operation to determine the exact pathological condition present, and that a certain proportion of the pathological conditions are removable, it is evident that an operation if not attended with danger may be reasonably undertaken. Some patients have undoubtedly been cured.
>
> The statement should be made to the patient: You have a brain disease; that disease is causing fits; that disease may be curable by operation; we cannot tell whether it is curable until we operate; we cannot promise that the operation will in any way benefit; a majority of chances are against cure, but it is the only method of treatment which affords any hope whatever, and it is a method which is fairly safe.

Surgery of the Spine

The first successful laminectomy for the relief of pressure upon the spinal cord causing paraplegia to be placed on record after introduction of listerian antiseptic surgery was that of the patient operated upon May 9, 1883, by Macewen (294). This case was presented by him to the Medical Surgical Society of Glasgow on February 15, 1884, and first reported in the *Glasgow Medical Journal* of that year. The patient was a 9 year old boy who for 3 years had had a progressive angular curvature of the spine, most marked between the fifth and seventh dorsal vertebrae. At the time that he was operated upon the curvature had become fixed by ankylosis of the bodies of the vertebrae. At operation the laminae of the fifth, sixth, and seventh dorsal vertebrae were removed. Between the theca and the bone there was found a "fibrous neoplasm ⅛ inch in thickness" which was firmly attached to the theca and covered about two-thirds of its circumference. This was carefully dissected off. Pulsations of the cord were then seen for the first time. The first return of movement took place 8 days later and this was soon followed by return of voluntary sphincter control. Macewen's report indicates that 6 months later the patient walked without support.

On December 22, 1885, Macewen (296) presented to the Glasgow Pathological and Clinical Society 2 cases of laminectomy for relief of spinal cord compression causing paraplegia, with almost total return of function in both cases. This article was printed in the Transactions of the Glasgow Pathological and Clinical Society for December 22, 1885; in the *Glasgow Medical Journal* for December 22, 1885, volume 25, page 210; and also in the *British Medical Journal* for December 1885, volume 2. The first of these 2 cases was the same which he had presented previously (294); the second was a case in which two thoracic laminae had been fractured by violence and driven in upon the cord, which resulted in a complete paraplegia and loss of sphincter control that had been present for 3 weeks before Macewen operated. The two fractured laminae were elevated; "'a dense connective tissue tumor' existed between the bone and the theca . . . the portion of the cord thus exposed was shrunken to about one-half of its normal dimension and lay like an inanimate rod . . . ." On the fourth postoperative day the patient had continence of the urine and feces, and soon thereafter sensation quickly returned. Six months after operation the patient could move her limbs freely and 8 months after operation she walked a quarter of a mile.

The first successful surgical removal of a true spinal cord tumor (neoplasm) was performed by Horsley (212) on June 9, 1887, and reported on

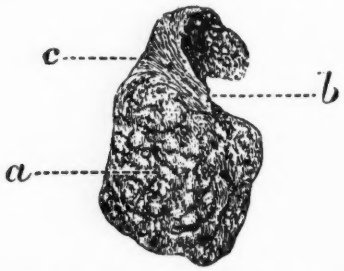

FIG. 4. The first spinal cord tumor to be successfully removed with complete recovery of the patient. The operation was performed by Horsley in 1887. Although diagnosed then as a "myxoma," it probably was a meningioma.

June 12, 1888 in a paper read before the Royal Medical and Chirurgical Society of London. This was a comprehensive paper which had great influence on the subsequent course of spinal surgery. In this paper Horsley gave a list of all of the cases of verified spinal tumors found in the literature up to that time. There were 58 such cases, in only 2 of which operation had been done and in only 1 (Horsley's case) permanent cure obtained. The other 56 patients, to quote Horsley directly, "had usually been made more hopelessly miserable by free use of the actual cautery, moxas and blisters, while in other instances the additional employment of mercury, iodide potassium, etc., had been resorted to." The diagnosis in almost all of these 58 cases was confirmed by autopsy, and "the melancholy inspired by consideration of the treatment given these patients is intensified by the fact that in no less than 74 per cent of the extradural growths and 83 per cent of the intradural growths, the patient died simply from the direct effects of the tumor; that is, from exhaustion, pain or pyemia owing to absorption from bedsores or from septic pneumonia or from acute septic interstitial nephritis. Roughly speaking, about 70 per cent of these miserable cases could have been relieved entirely by operation and those which were hopeless might, by relief of pressure, have been granted an euthanasia."

Horsley's case had been referred to him by Gowers who had made the diagnosis of spinal cord tumor and given Horsley a segmental location for the tumor. At operation Horsley first removed the spines and laminae of the fourth, fifth, and sixth thoracic vertebrae, but upon opening the dura he found no tumor. A lamina above and a lamina below were then removed, but still nothing pathologic was found. Horsley then writes, "at this juncture it appeared as if sufficient had been done, but I was unwilling to leave the matter undecided, and my friend, Mr. Ballance, being sharply of the opinion that further exposure of the cord was indicated, I determined to go further. I removed another lamina at the upper part of the incision. On opening the dura mater, I saw on the left side a round, dark, bluish mass about 3 mm. in diameter . . . I recognized it at once to be the lower end of a new growth and therefore quickly cut away the major part of the lamina next above. This enabled me to see almost the whole extent of the tumor when the dura mater was divided. The growth was found by measurement to be 4 inches above the level of complete anesthesia"[2]. This tumor was completely removed; it was diagnosed as a "myxoma," but probably was a fibroblastoma or meningioma (FIG. 4). The patient experienced a smooth postoperative course and made a rapid recovery from his previous paralytic symptoms.

Horsley's pre-eminence and the consequent wide dissemination of the knowledge of his successful removal of a tumor from the spinal cord did much to dissipate the prejudice against laminectomy which had existed from the pre-listerian days, when meningitis leading to death was so common, and had an incalculable effect in furthering the cause of spinal cord surgery.

In August, 1888 Macewen (297) delivered an important address before the British Medical Association on the subject of "Surgery of the Brain and Spinal Cord." In addition to reporting 21 cases of intracranial surgery, he reported 6 cases of spinal surgery: case 1 and case 2 were the cases to which we have already alluded; case 3 he disposed of simply by saying, "This case was also successful," but added no other description; cases 4 and 5 were both laminectomies performed for cord compression resulting from marked kyphosis of the thoracic spine due to tuberculosis, and both patients died of their disease, one week and several months, respectively, after operation; case 6, reported in detail, was that of a 22 year old coal miner who had complete paraplegia and incontinence following a fall with injury to the twelfth thoracic and first lumbar vertebrae. At operation "the arch of the 12th dorsal was found fractured and slightly de-

[2]What neurosurgeon has not had this experience, in spite of his best clinical effort to establish the exact level of the tumor preoperatively?

pressed. Between it and the theca there existed a connective tissue tumor measuring nearly ¼ inch in antero-posterior diameter and extending from the 11th dorsal to the 2nd lumbar .... This tumor was carefully dissected from the theca ... [the patient] began to move his toes on the third day .... He was soon able to walk with support ... which a year later he discarded."

One may infer that Macewen had become a bit jealous of the attention and acclaim which had come to Horsley following Horsley's report (212) of the first successful removal of a true spinal cord neoplasm (1886) with full recovery of function, for Macewen ends his address with these words:

> Here, therefore, are 6 cases in which elevation of the posterior laminae of the vertebrae has been performed .... Such operations are now beginning to be practiced by others. Mr. Horsley a few months ago published a successful case in which a somewhat similar operation had been performed for the removal of a *small tumor* of the theca *diagnosed by Dr. Gowers.*

It seems probable that Macewen would have liked the distinction of having removed the first spinal cord tumor as evidenced by the fact that on several occasions he speaks of removing "connective tissue tumors" in his first and second cases of laminectomy. Careful reading of the original reports, however, clearly establishes the fact that cord compression in all of Macewen's cases was caused either by posttraumatic or postinflammatory granulation tissue; in none of his cases was compression of the cord caused by a neoplasm. Clear priority for the first removal of a spinal cord neoplasm, with operative survival and recovery of function, belongs to Horsley.

The first successful removal of a spinal tumor in the United States was performed in 1889 by Abbe (1), who removed the spines and laminae of the eighth, ninth, and tenth thoracic vertebrae and dissected away from the dura, without opening it, a dense extradural mass of tissue compressing the spinal cord. Although the patient had been paralyzed and incontinent of urine before operation he subsequently became able to walk and was entirely well for 2 years; then some discharge appeared in the wound and it was consequently assumed that the mass which had been excised was a tuberculoma. This case was reported before the New York Medical Society in February, 1889. The second successful removal of an extradural tumor in this country was performed by Abbe (3) in April, 1890. In this same year he published a report of 8 cases of spinal surgery and in 1892 he published a paper on the surgical treatment of syringomyelia (4).

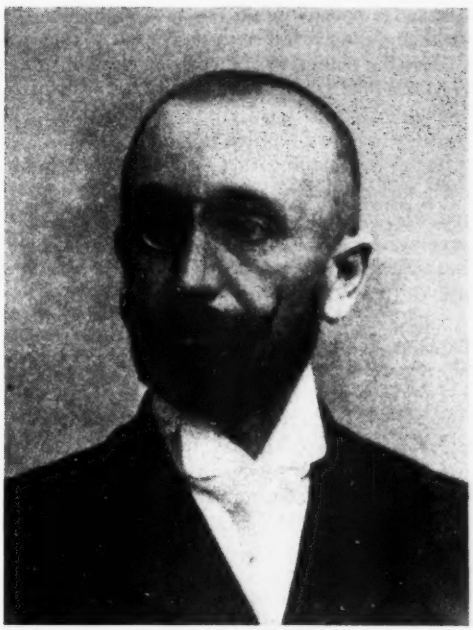

FIG. 5. A. Chipault.

In 1895 Starr (449) was able to collect from the literature 22 cases of spinal cord tumor in which operation had been done. In only 2 instances had the surgeon failed to find a tumor, and in one case it was impossible to remove the tumor when found. However, there were 11 operative deaths (50 per cent mortality!), and of the 11 patients who survived operation, only 6 (25 per cent) recovered in any degree from their paraplegia. Unfortunately Starr did not identify the 6 successful cases nor the surgeons responsible for them.

Chipault (56,57) (FIG. 5), in 1894, reported 22 cases of spinal tumor collected from the literature in which operation was done; presumably they were the same 22 cases collected by Starr during the previous year.

In 1895 Keen (260) referred to the 22 cases of spinal tumors collected by Chipault, to which he added 3 additional cases of his own, thus making a total of 25 cases. The figures thus reported by

Starr, Chipault, and Keen are essentially the same and may be taken as representing approximately the true state of surgery in cases of spinal cord tumors in the year 1895. No comprehensive reports of spinal cord surgery were published during the years 1895 to 1905.

Before concluding this brief survey of spinal cord surgery prior to 1905, mention should be made of another valuable contribution to spinal surgery made during this period, namely, the intradural section of the dorsal roots of spinal nerves (posterior rhizotomy) for the relief of intractable pain. This operation was first proposed by Dana, and first performed by Abbe in 1888 (5). Credit for suggesting dorsal root section has been erroneously ascribed to Frazier. It was not until 1910 that Frazier (445) reported his first dorsal root section, and in that report he credited Spiller with first suggesting the operation in 1905. It will be seen from this that Spiller's suggestion was made 15 years after Dana's, and that Frazier's operation was performed 20 years after Abbe's—facts which have only recently been called to our attention by Stookey (462).

It is also to be noted for the record that Abbe (5) was the first to stimulate intradurally a discrete motor root by electricity and to record the individual muscles which responded, for the purpose of establishing the precise segmental level of his surgical exposure of the spinal cord.

The total number of cases of spinal surgery reported in the literature prior to 1905 is surprisingly small, the mortality incredibly high, and survival with symptomatic recovery pathetically low. These facts are difficult to explain when one considers that 22 years had elapsed since Macewen removed an extradural "fibrous tumor," and 18 years had elapsed since Horsley had successfully removed an intradural meningioma.

Trigeminal Neuralgia

The story of the attempts to relieve trigeminal neuralgia is a small medical history in itself. It is said (251) that Galen suggested section of "the nerve." Unfortunately the facial, or motor, nerve to the face was supposed by him to be at fault. This nerve was eventually sectioned by Mareschal, Body-Surgeon to Louis XIV; the pain, of course, was not relieved and paralysis of the face naturally resulted. The operation consequently fell into disrepute. For many years, therefore, the treatment of trigeminal neuralgia remained entirely medical. Even as late as 1884 it was reported that good results were frequently obtained from the use of quinine, arsenic, gelsemium, antipirin, and the bromides; Seguin, later Professor of Nervous and Mental Diseases, of the College of Physicians and Surgeons, Columbia University, New York, recommended chloride of ammonia and aconitine, which he said must be pushed until its physiological effect is fully experienced; ethyl chloride was used. Some recommended counter-irritation in the form of blisters over the point of emergence of the nerve or along its course; others attached great importance to the use of galvanism, and it was reported that the results of this treatment were "as good as can be got from any method of treatment."

Later, operative procedures were carried out on the various peripheral branches of the fifth nerve, which included stretching, division, excision, and avulsion of these nerves.

As time went on, however, it became more and more evident that none of these forms of surgery directed to the peripheral divisions of the nerve were effective.

In 1858 Carnochan (48) conceived the idea that the sphenopalatine (Meckel's) ganglion had to be excised, and developed an operation through the maxillary sinus to reach this ganglion, which he removed with a portion of the second division of the trigeminal nerve. In order to provide better visibility, Goerste (in 1884) temporarily excised the upper jaw; Lucke (in 1875) divided the zygoma and reflected it upward to expose the sphenomaxillary fossa, where he excised the ganglion and a section of the nerve; and Lussen (in 1876), dividing the zygoma, turned it downward to expose the pterygoid fossa and resect the sphenopalatine ganglion and the second and third divisions of the nerve.

However, none of these operations dividing the trigeminus external to the skull provided permanent relief, and the opinion gradually took form that this could be achieved only by extirpation of the gasserian ganglion itself.

As a result of this thinking, Rose (400) of London, in 1890, was the first to perform removal of the gasserian ganglion. Rose approached the external opening of the foramen ovale through the pterygoid fossa, enlarged the foramen with a small motor-driven drill, introduced instruments through this enlarged opening into the cranial fossa, and avulsed, piecemeal, the gan-

glion. The operation was technically difficult and bloody, visibility was poor, and the removal of the ganglion usually incomplete. Although performed by Rose a number of times, this operation was not satisfactory, even in his hands, and was never widely accepted.

Into this confused situation the calm reasoning of Horsley (251) came like oil poured on troubled waters; I quote him directly to show the striking clarity of his surgical thinking:

In considering the possibility of relieving cases of inveterate neuralgia where recurrence of the pain had taken place, I thought one might be able to remove the Gasserian ganglion or divide the fifth nerve behind it, and I made, some years ago, dissection to see how far the Gasserian ganglion could be separated from the cavernous sinus. On first exposing the ganglion from the pterygoid fossa and opening the middle fossa of the skull, freely following up the inferior division of the fifth nerve, I found that one could raise the inferior division and free the lower half of the ganglion from its bed in the dura mater without damage to the carotid artery in the canal or to the cavernous sinus; but that when one attempted to strip up the upper half of the ganglion from the cavernous sinus it invariably tore the wall of that cavity. For this reason I believe that the operation of complete removal of the Gasserian ganglion is not possible but that in the operation which Mr. Rose has subsequently described only a portion of it can be taken away.

Finding this to be the case, *I then considered the possibility of dividing the fifth nerve behind the ganglion.* It is well known that the fifth nerve enters the dura mater just beneath the edge of the tentorium and that it runs afterwards in a small but roomy canal[3] in the dura mater, joining the Gasserian ganglion, which lies in a similar cleft on the upper surface of the petrous bone and on the roof of the carotid canal. Some experiments on the monkey to expose the crura had shown me that it was possible to expose the temporo-sphenoidal lobe, and then, by raising the brain carefully with a broad retractor, to lay bare the floor of the middle fossa of the skull. In trying this on the dead body, I found it was perfectly possible in man also, the only trouble being the small veins which come from the temporo-sphenoidal lobe and which enter the petrosal sinuses. If these be ruptured the hemorrhage is very free, and, although not dangerous to life, nevertheless very effectively injures the performance of the operation.

This exposure of the temporo-sphenoidal lobe in man I have carried out by making a large temporal flap starting from the anterior extremity of the zygomatic process, and running upwards to the temporal ridge, following that line and descending along it to the asterion. The temporal muscle after being separated from the bone is then best removed so far as this posterior half is concerned and then the whole of the squamous portion of the temporal taken away by means of a trephined opening and suitable bone forceps. Anteriorly the middle meningeal artery may be dealt with where exposed, being simply ligatured in the dura mater. The dura mater is then to be opened along the full length of the area of the bone removed and the temporo-sphenoidal lobe thus laid bare. A broad copper retractor with smooth and inverted edges is then gently slipped underneath the lobe and slowly but steadily raised. The lobe is partly molded, partly lifted upwards, and the floor of the skull is then easily seen and illuminated with electric light. The guide to the fifth nerve now is the upper border of the petrous bone. The lobe being raised a little more, the edge of the tentorium will be defined and the point at which the fifth nerve passes beneath it could in the first case I operated upon be seen. The position of the canal in which the nerve is lying just above the ganglion must then be estimated and a small puncturing incision made into it. As it is about ¼ inch in diameter it can be recognized as soon as the puncturing instrument passes into it, and the dura forming its roof should then be further slit open. The nerve in this way is exposed and is found to be freely lying in the little passage.

The first case on which I operated in this manner [December 11, 1890] was [a] patient in whom I had . . . previously removed a portion of the inferior dental and the infraorbital nerves. . . . The operation presented no special difficulty beyond that of being very tedious. I resected the zygoma in order to have more room, but I feel sure now that that was a useless complication—that it was quite possible to have reached the nerve without it, and I regret having done it because I think it of course aided in producing the shock which caused the fatal termination of the case. . . . On opening the dura mater the brain bulged moderately. . . . On exposing the nerve in the canal behind the ganglion I passed a small blunt hook around it . . . and on generally drawing on it with the hook this [avulsion] was easily accomplished, and without even any noteworthy oozing. The wound was closed in the usual way. Unfortunately, the patient never rallied from the operation and died 7 hours afterwards obviously from shock.

At the post mortem examination which I obtained with some difficulty . . . I found that there was no cause of death except that already mentioned. There had been a slight amount of oozing into the subarachnoid space but nothing to produce any compression at all. . . . On reviewing the result of this operation I am satisfied that the unfavorable termination was due to the special circumstances of the case [that is, the extreme debilitation of the patient], and a considerable series of experiments on the lower animals which have been made involving the division of the fifth nerve now clearly show that the mere exposure and section of the nerve is not in itself dangerous to life.

What a great pity that this first section of the sensory root of the trigeminal nerve was attempted in such a debilitated patient and ended in death; for despite Horsley's correct interpretation of the result and his correct rationalization that division of the sensory root per se

[3]See Taarnhoj's operation.

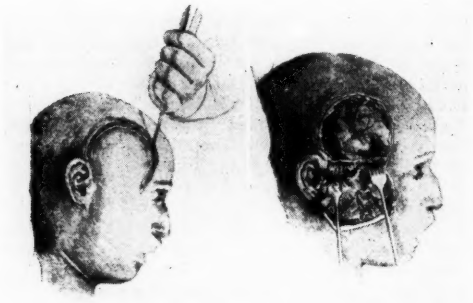

FIG. 6. The first successful and permanent cure of trigeminal neuralgia was achieved by Hartley of New York in 1891. He entered the skull through a small right temporal osteoplastic flap, cutting through the bone with a chisel and mallet in the manner first described by Wagner. The gasserian ganglion was then approached *extradurally* along the floor of the temporal fossa. The ganglion itself was then totally extirpated.

A similar operation was performed by Krause of Berlin 6 months later.

should not be a dangerous procedure, he nevertheless, for some inexplicable reason, allowed himself to be deflected away from his original, beautifully conceived operation and never again attempted it. It was not until 19 years had elapsed that Frazier (445), at Spiller's suggestion, did successfully section the sensory root of the ganglion and established the technique which was to become the standard method of relieving this pain—a technique standard even today.

The first total extirpation of the gasserian ganglion and the first permanent cure of trigeminal neuralgia was achieved by Hartley (223) in 1891, just 8 months after Horsley's ill-fated posterior root section. Hartley used a low temporal osteoplastic flap (FIG. 6), following the technique of Wagner, and opened the skull with mallet and chisel. He then used an extradural approach along the floor of the temporal fossa to reach the gasserian ganglion, which he totally removed. This operation was performed on August 15, 1891, was described before the New York Surgical Society on January 13, 1892, and was published in the *Medical Record* on March 19, 1892, and again in the *Annals of Surgery* in 1893.

Entirely unaware of Hartley's operation, Krause (270) (FIG. 7) of Berlin performed an almost identical operation on February 23, 1892, which he described and published in the *Archiv fur klinische Chirurgie*, October 11, 1892. Extirpation of the gasserian ganglion by an extradural approach along the floor of the middle fossa has long been generally designated as the "Krause-Hartley" operation, although it is evident from the record that Hartley performed his operation 6 months before Krause and should, therefore, have clear priority in this matter.

In December, 1893 Keen (262) performed his first successful gasserian ganglionectomy, which he reported to the Philadelphia County Medical Society on February 14, 1894, and published under a rather ambiguous and misleading title in the proceedings of that society for 1894. In 1896 Keen (261) reported 5 additional cases without a death. Complete relief of pain was obtained in all 6 cases. This report is a very fine and comprehensive article giving in great detail the status of this operation at that time and discussing in almost a modern manner the management of such complications as corneal ulceration from taping the eyelids closed to suturing them. In this article *Keen suggested for the first time in the recorded literature that the motor root might be spared* (FIG. 8):

> The connection between the ganglion and its sensory root is apparently so strong that this root almost always comes away with the ganglion. In my last case the slender cord passing under the ganglion cannot, it seems to me, be other than the motor root. Whether it would be possible to separate the motor root from the ganglion and the third division, I do not yet know. I should propose in another suitable case to see whether it is not possible to lift the ganglion and separate it and the third division from the motor root and then by cutting the third division of the fifth in a direction away from the motor root possibly to preserve this nerve.

In 1895 Krause (271,272) had been able to collect from the literature 51 gasserian ganglionectomies performed by the Hartley-Krause technique with an over-all mortality of approximately 10 per cent.

In 1900 we find Horsley, (244) in an address on the surgical treatment of trigeminal neuralgia, reporting 21 cases in which he had excised the gasserian ganglion. His results with this difficult operation were quite good, there being only 2 deaths in 21 operations (10 per cent); one of a man 62 years old who died 2 months after the operation from a staphylococcus meningitis which may have arisen from extension of a syphilitic ulceration in the nose, and the other of a woman 80 years old who exhibited no symptoms of shock during the operation but who, a

few hours later, as she was being given "an enema of beef tea," suddenly became unconscious and exhibited all the obvious signs of apoplexy; she died 2 days later, and postmortem examination revealed a small hemorrhage deep in the pons. In this article Horsley reports no further attempts at section of the dorsal root other than his first ill-fated case, but he makes the following reference to dorsal root section:

> Some 14 years ago, Professor Macewen and myself, both independently, thought not of removing the ganglion, because we knew of its intimate relation to the wall of the cavernous sinus, but of dividing the sensory root of the nerve behind the ganglion thus making sure we cut off all possible paths between the ganglion cells and the central apparatus of the nerve. We both did much the same thing. We opened the skull, raised the temporo-sphenoidal lobe, and divided the sensory root. Unfortunately, in each case, the patient died, and they obviously died of shock due to the operation; and we both, quite independently, came to the conclusion that it was a dangerous operation, and that one did not feel justified in repeating it[4].

Summation

We have thus reviewed the birth of neurosurgery following the development of antiseptic surgery and the discovery of localization of function in the brain; the rush of the general surgeons to "stake their claims" in the new field; the discovery by most of them that they were ill-fitted by training or temperament for this new, arduous, and exacting work; the gradual growth of a formidable "mass-mortality" for brain surgery; the resulting discouragement and disillusionment of the general surgeon and his rapid withdrawal from neurosurgical ventures; and the period closing with the fallow and stagnant decade from 1895 to 1905.

During this period, prior to 1905, however, four great neurosurgical giants emerged: Macewen (FIG. 1), Horsley (FIG. 2), Krause (FIG. 7), and Chipault (FIG. 5). Macewen was a rugged individualist and pioneer, and he has to his credit several memorable "firsts." However, he remained inherently a general surgeon and never became a neurosurgeon at heart, and doubtless for this reason he never made any fundamental contributions to neurosurgery. However, probably for this very same reason, he realized greater success in the handling of infections of the brain than any contemporary surgeon or, indeed, any subsequent neurological surgeon until

[4]No other reference to Macewen's early operation for trigeminal neuralgia appears in the literature.

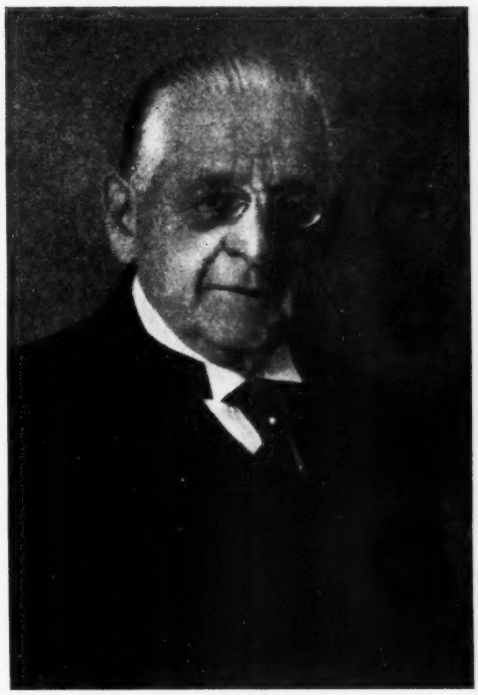

FIG. 7. Fedor Krause.

the advent of the antibiotics. His volume on "The Pyogenic Infectious Diseases of the Brain and Spinal Cord" (296) (FIG. 9-a), published in 1893, is unique in its field and still stands today as one of the great medical classics. Krause came from a different mold. He was shy, cautious, methodical and self-effacing; yet Krause's three volumes on "Surgery of the Brain" (273)

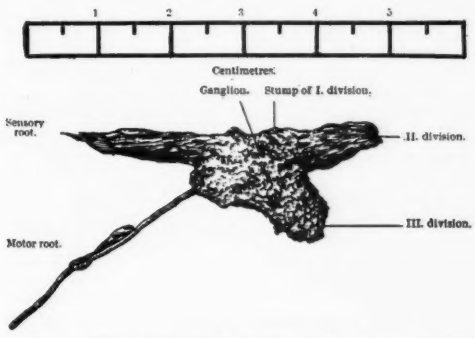

FIG. 8. Gasserian ganglion removed by Keen (1895) for relief of trigeminal neuralgia.

PYOGENIC
INFECTIVE DISEASES
OF THE
BRAIN AND SPINAL CORD

MENINGITIS
ABSCESS OF BRAIN
INFECTIVE SINUS THROMBOSIS

BY
WILLIAM MACEWEN, M.D.
GLASGOW

NEW YORK
MACMILLAN AND CO.
1893
a

SURGERY
OF THE
BRAIN AND SPINAL CORD
BASED ON PERSONAL EXPERIENCES

BY
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GEH. MEDIZINALRAT
DIRIGIERENDER ARZT AM AUGUSTA HOSPITAL ZU BERLIN

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b

FIG. 9. Title pages of four medical classics published prior to 1905: a, b, c, d.

FIG. 9b), published 1908-1911 are magnificent. They reveal Krause as a neurosurgeon far ahead of his time and establish him unquestionably as one of neurosurgery's great men. Chipault held a position in respect to spinal surgery of this period similar to that which Krause held in respect to cranial surgery. Chipault's thinking was fundamental and not confused by contemporary trends. He did much to clarify the principles and to simplify the techniques of spinal surgery. His two fine works "Études de chirurgie médullaire" (56) (FIG. 9-c) and "Chirurgie opératoire du système nerveux" (in two volumes) (57) are also medical classics.

The greatest of all the early neurosurgeons was unquestionably Victor Horsley. During almost his entire professional life Horsley directed his keen mind and great energy toward the solution of fundamental problems of neurosurgery. Although compelled to practice neurosurgery for a livelihood, he nevertheless spent an incredible amount of time at work in his laboratory, which was done only at great personal financial cost. As a clinician Horsley's reasoning was limpid-clear; as a surgeon he was both bold and skillful, and scored many important neurosurgical "firsts;" but continuously, throughout his active surgical practice, he constantly applied the "laboratory methods" to his operating room procedures.

Although Horsley never published a volume on neurosurgery, as did Macewen, Krause, and Chipault, nevertheless his more than seventy-five publications on the most fundamental

ÉTUDES

DE

CHIRURGIE

MÉDULLAIRE

(HISTORIQUE, CHIRURGIE OPÉRATOIRE, TRAITEMENT)

PAR

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BRAIN SURGERY

BY

M. ALLEN STARR, M.D., PH.D.

PROFESSOR OF DISEASES OF THE MIND AND NERVOUS SYSTEM, COLLEGE OF PHYSICIANS AND SURGEONS, MEDICAL DEPARTMENT OF COLUMBIA COLLEGE, NEW YORK; PRESIDENT OF THE NEW YORK NEUROLOGICAL SOCIETY; CONSULTING NEUROLOGIST TO THE PRESBYTERIAN, ORTHOPÆDIC AND BABIES HOSPITALS

WITH FIFTY-NINE ILLUSTRATIONS

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BAILLIERE, TINDALL AND COX
1893

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aspects of neuroanatomy, neurophysiology, neurology, and neurosurgery constitute an imposing and indestructible monument to his greatness. He is truly the "father of neurosurgery." It is difficult to find more inspiring reading than that found in the story of Horsley's life (353).

PART II. NEUROSURGERY, 1905–1955

The Neurosurgeon

Introduction

In an address on "The Special Field of Neurological Surgery" published in March, 1905, Harvey Cushing (72), freshly appointed Associate Professor of Surgery at the Johns Hopkins Medical School (Fig. 10), sounded the keynote to the development of neurologic surgery during the next 50 years.

. . . *It seems clear that in order to advance surgical measures, specialization or, better, concentration of thoughts and energies along given lines is necessary.* . . . Those whose inclinations follow the branch of neurology must do their own surgery . . . and not depend on the help supplied by the lukewarm assistance of other departments.

To successfully cope with the many operative problems offered by the various disorders of the nervous system, a man, after a thorough training in pathology and medicine (in its broadest sense) must study, not only in the neurological clinic but also in the laboratory, the pathology of these afflictions in their histological and—what is still more important—in their experimental aspects.

. . . In talking the matter over with my surgical friends, many of them have expressed themselves emphatically against any form of operative specialization. But, granting the wisdom and the necessity of a general surgical training beforehand, I do not see how such particularization of work can be avoided if we wish more surely and progressively to advance our manipulative therapy.

Are practice of hand and concentration of thought to go for nothing?

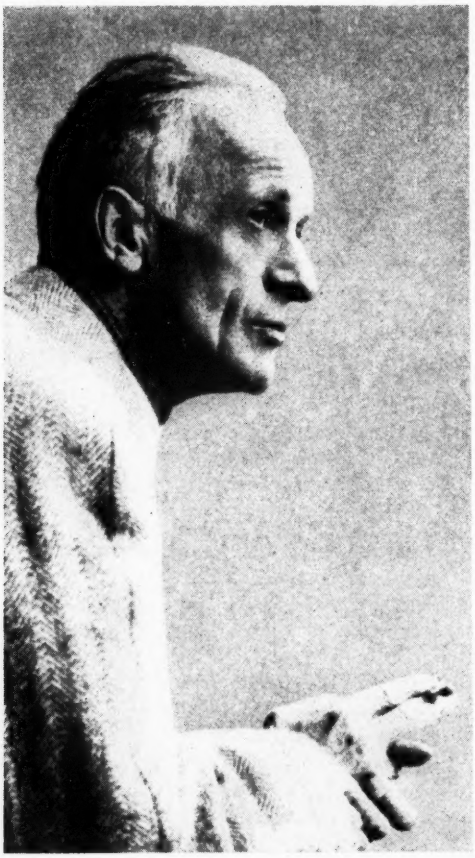


FIG. 10. Harvey Cushing.

The years 1905 to 1955 mark the growth of the neurosurgical specialist and the neurosurgical specialty. As the story gradually unfolds, three phases are recognizable: first, the development of operative and diagnostic skills permitting the surgeon to locate his lesion, reach it, and deal effectively with it without prohibitive mortality; second, the classification of tumors removed at operation and the correlation of these tumors with clinical syndromes; and third, the applications of the methods and critiques of the physiologic laboratory to the study of the human living brain in the operating room.

Although these three phases tend to succeed one another in the chronological order mentioned, considerable overlap of the three phases has occurred throughout the evolution of neurosurgery. As an illustration, efforts to "map"the focal representation of function in the human cortex naturally followed the early mapping of animals' brains which opened up the field of neurosurgery; and so we find physiologic studies taking place during the early years which were devoted principally to expansion of surgical techniques. Conversely, today, in the midst of most complex physiologic studies of the brain we find described three new surgical techniques for the treatment of trigeminal neuralgia. In general, however, the three phases in the development of neurosurgery follow one another in sequence, and recognition of these successive phases provides a protocol for narrating the evolution of neurologic surgery.

A. THE SURGICAL PHASE
THE DEVELOPMENT OF OPERATIVE AND DIAGNOSTIC TECHNIQUES

As the curtain rose on "the age of specialization," the new generation of neurosurgeons was

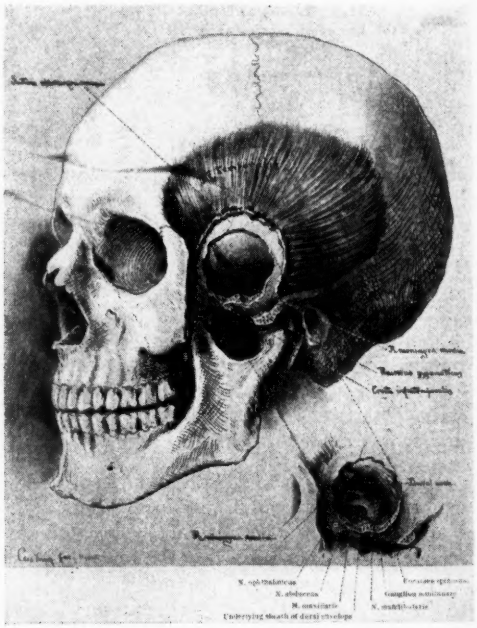


FIG. 11. Cushing's first important clinical paper on a neurosurgical subject was a description of a technical improvement of Hartley's extirpation of the gasserian ganglion for the treatment of trigeminal neuralgia. Cushing himself drew the above figure and illustrated many of his other early articles.

confronted with two immediate problems left unsolved by their predecessors: (1) a surgically acceptable treatment for trigeminal neuralgia, and (2) a reduction in the forbidding mortality which till then had attended the surgery of brain tumors.

Trigeminal Neuralgia

Cushing's first important clinical paper in the field of neurosurgery, entitled "A Method of Total Extirpation of the Gasserian Ganglion for Trigeminal Neuralgia by a Route through the Temporal Fossa and beneath the Middle Meningeal Artery," had already been published in 1900 (69). This paper is of interest today because even then it revealed some of Cushing's traits of mind and habits of work. The basic operation for the relief of trigeminal neuralgia by extirpation of the gasserian ganglion had already been worked out by Hartley (223) and Krause (270), as outlined in the previous section of this narrative, and was being used by an increasing number of surgeons. The average mortality for this period approximated 20 per cent (188). However, the operative mortality, even in the hands of the most skillful surgeons, was high (approximately 10 per cent) and was due principally to uncontrolled hemorrhage from the middle meningeal artery which would be torn when the temporal dura was being elevated.

Cushing's contribution was a modification of the Hartley-Krause operation; he temporarily resected the zygomatic arch and retracted it downward, which permitted him a low, direct approach to the gasserian ganglion, requiring minimal elevation of the temporal lobe and minimal traction upon the middle meningeal artery (FIG. 11). In 1907 he reported that in 30 cases in which he had undertaken to extirpate the gasserian ganglion he had in no instance torn the middle meningeal artery (75). Later in 1907 (76) he reported that only once in his entire series of 62 ganglion operations had he injured this artery, a truly incredible record[5].

In 1905 Cushing (70) reported 20 cases of extirpation by him of the gasserian ganglion with only one death, an operative mortality of just 5 per cent. He undoubtedly intended this paper to be an "opus major"; his series was the largest which had, up to that time, been reported by any American surgeon[6]; his case reports were completely documented with detailed histories, examinations, operative notes, photographs of specimens and patients, and long-term follow-up examinations; the paper was 30 pages in length; moreover, his operative mortality (5 per cent) was only about one-half the average for the times. This authoritative communication on the difficult operation of gasserian ganglionectomy undoubtedly immediately gave Cushing national recognition in the neurosurgical field. However, his satisfaction from this achievement was short-lived, for reasons we shall see.

FIG. 12. Charles H. Frazier.

In 1901 Frazier (442) (FIG. 12) at Spiller's suggestion, had successfully relieved trigeminal neuralgia by simply dividing the sensory root behind the ganglion (FIG. 13), an operation which inherently reduced many-fold the opera-

[5]Interesting features of these early publications of Cushing are the beautiful drawings with which he illustrated his own articles. There can be no doubt but that he had considerable talent for drawing, which he cultivated during his training years at Johns Hopkins under the tutelage of his friend Max Brödel, the great dean of medical illustrators. Cushing liked nothing better than to illustrate his operations with original sketches, although as he became busier and more pressed for time these sketches became progressively less detailed and finished and were used for his own orientation rather than for publication.

[6]Horsley, in 1890, had reported 21 cases of total ganglionectomy with 2 deaths (10% mortality); Krause, in 1895, had collected 51 cases from the literature with a mortality of approximately 10 per cent.

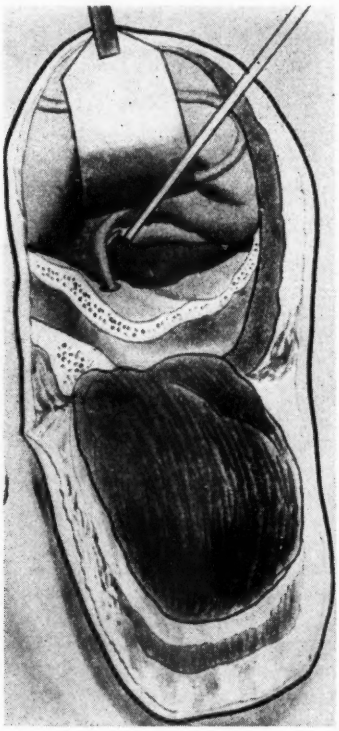


FIG. 13. Illustration taken from the original article by Frazier, describing the first successful cure of trigeminal neuralgia by simple division of the sensory root.

tive risks by eliminating the hazardous dissection of the gasserian ganglion from the thin lateral wall of the cavernous sinus. This one successful operation, originally conceived but unsuccessfully performed in 1890 by both Horsley (251) and Macewen, sealed the doom of "gasserian ganglionectomy."

The subsequent story of Cushing in respect to the surgical relief of trigeminal neuralgia is interesting. Even after Frazier's report of dorsal root section in 1901, Cushing had continued to insist in all of his writings, even in the 1905 publication, that extirpation was the only certain means of totally and permanently curing this affliction.

In 1906, however, he (73) reported 5 additional cases operated upon by him for the relief of trigeminal pain; in 4 of these he had removed the entire gasserian ganglion, as usual, but in the fifth case he had had to content himself with simple division of the posterior root because of a tumor involving the floor of the middle fossa. All 5 patients were equally relieved of their pain.

In the following year (75) Cushing read another paper on the surgical relief of trigeminal neuralgia; this paper is amusing when it is recalled that only the previous year Cushing had insisted, in his important paper, that only by total extirpation of the ganglion could permanent relief be obtained:

> At Spiller's suggestion, Frazier, using the method of approach *which I had described*, endeavored to simplify the treatment of the ganglion by simple section of the trigeminal root proximal to the ganglion . . . [and] succeeded in carrying out this measure in certain cases which he has recorded.
>
> We are not yet assured that there can be no reunion of function after simple division of the sensory nerve root, provided the severed ends are left sufficiently near for a neurotropic influence to act on the outgrowing axones from the cells of the root-ganglion.
>
> I think that *I have been able to overcome the objections* to the total enucleation procedure and, at the same time, to assure . . . certainty of permanent relief *by a simple withdrawal in toto* [*avulsion*] *of the sensory root* . . . (!)[7].

With this adroit turnabout Cushing abruptly concluded his contributions to the surgery of trigeminal neuralgia and almost fiercely turned his energies toward attack on the other much more formidable problem of reducing the mortality in the surgery of brain tumors—a task which was to hold his almost undivided attention for the next 25 years.

It is interesting to note that Frazier's (442) very first recorded contribution to intracranial surgery, like Cushing's, was on the treatment of trigeminal neuralgia. There is, moreover, considerable drama in the fact that this one simple operation put the "quietus" for all time to all the tedious and harrowing work of Hartley, Krause, Horsley, Keen and Cushing, spent in developing total excision of the gasserian ganglion. Perhaps because his initial contribution was such a brilliant success, Frazier, unlike Cushing, continued his interest in the surgery of trigeminal neuralgia (190, 180, 187, 189).

[7]Cushing had apparently read Frazier's article hastily, for in it Frazier states:

"The division of the root is not a difficult performance. When fully exposed it is picked up on a blunt hook, which is passed around the nerve from without inwards. The nerve is divided either by making traction with the hook or cutting directly upon the hook with knife and scissors. It would be a better plan, however, and I will carry it out in future cases, to grasp it with a pair of forceps and remove a small section with knife or scissors."

In his original paper Frazier discusses the possibility of further improvement in the operation by the sparing of the motor root[8]:

> Can the sensory root be isolated from the motor root so that the integrity of the latter may be preserved? This question may be answered in the affirmative if certain reservations be made; that is, it is possible upon the living subject to separate the motor from the sensory root as proven in my own case. I had concluded the operation and was about to close the wound; in order to assure myself that none of the fibers of the sensory root had been undivided, I repeated the last step of the operation, and in the doing I picked up the motor root which up to this time had remained intact, and unintentionally divided it. It is possible therefore to divide the sensory root without the motor root; whether we can attain sufficient dexterity to avoid the accident which happened in my case is a matter to be settled by future repeated observations.

Curiously, however, it was not until 1919 that Frazier began the practice of regularly sparing the motor root, and it is even more curious that he did not call attention to this fact until 1925 (187) and did not report it in his writings until 1934 (189). Frazier has usually been accredited with first sparing the motor root in the operation for trigeminal neuralgia, but priority undoubtedly belongs to Peet (355), who in 1918 reported a number of cases in which he had saved the motor root in operations during the previous year[9].

Frazier in 1915 began practicing subtotal division of the root to spare the ophthalmic fibers and avoid postoperative keratitis, although he curiously did not report this until 1925 (187). In 1905 Frazier (178) also mentioned that section of the sensory root through a posterior fossa approach was feasible, but this operation was first performed successfully by Dandy (120) in 1925. Quite recently several new types of operations for the relief of trigeminal neuralgia have been proposed which will be described later on in this narrative, but for the time being a thoroughly feasible method for the surgical treatment of trigeminal neuralgia had been provided by Frazier's dorsal root section, which by 1907 or 1908 had been widely accepted, even by such earlier skeptics as Cushing.

[8]This had previously been proposed by Keen, in 1896, who expressed the opinion that this should be possible even with the total excision of the ganglion.

[9]Horrax states that Cushing, although he never reported it was almost certainly the first surgeon who actually did save the motor division in such an operation:

"The patient was L. D., a 76 year old male, surgical number 2822 in the Peter Bent Brigham Hospital records, and the operation was performed on June 7, 1916. Included in the patient's record there is an operative sketch by Dr. Cushing showing how the motor root was spared. The patient was referred by Dr. J. Ramsay Hunt of New York."

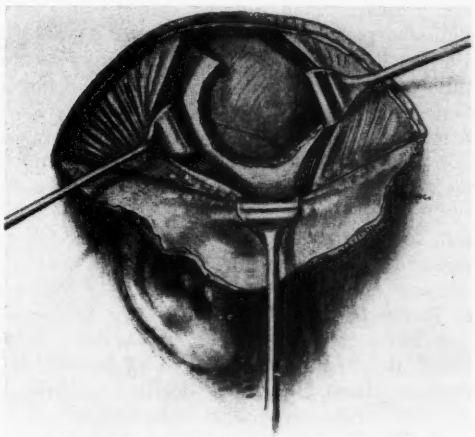


FIG. 14. Cushing's subtemporal decompression. The first description of this famous operation was published in 1905, in the first volume of SURGERY, GYNECOLOGY AND OBSTETRICS. The drawing was made by Cushing.

Palliative Decompressions

As the furor over the surgical treatment of trigeminal neuralgia gradually subsided, a new neurosurgical interest became evident from a survey of the literature of this period; namely, the development of palliative decompressive procedures for the relief of intracranial pressure. In 1905, in the very first volume of "SURGERY, GYNECOLOGY AND OBSTETRICS," we find a paper by Cushing (71) entitled "The Establishment of Cerebral Hernia as a Decompressive Measure for Brain Tumors; with the Description of Intermuscular Methods of Making the Bone Defect in Temporal and Occipital Regions." This was the first description by Cushing of his famous "subtemporal decompression" (FIG. 14). Before this, in order to relieve intracranial pressure from tumors either not found or not removed, it had been general practice simply to leave the dura open and remove the bone, closing only the skin. These "decompressions" would be left over any part of the cranial convexity; as the intracranial pressure would mount, the skin would progressively stretch until monstrous herniation would develop (FIG. 15-a). Cushing, by keeping his decompression under the supporting temporal or occipital muscles, relieved the intracranial tension enough to stop headache

and preserve vision, without incurring the unsightly herniation of the brain (Fig. 15-b). In 1907 we find a second paper by Cushing (74) on this same subject, in 1908 (77,78,107) three more papers; and in 1909 (80) still another paper describing "A Method of Combining Exploration and Decompression for Cerebral Tumors which Prove to be Inoperable."

The following year (1906) Frazier (444), in collaboration with Spiller, published a long and impressive article entitled "Cerebral Decompression. Palliative Operations in the Treatment of Tumor of the Brain Based on the Observations of Fourteen Cases." He begins this article with a detailed historical review of decompressive procedures, followed by detailed case histories of 14 patients on whom he had performed such operations between the years 1898 and 1906, both for cerebral and cerebellar tumors. Apparently Cushing (84) thought that Frazier was trying to "steal his thunder" on the subject of subtemporal and suboccipital decompressions and did not like it, for we find him writing with asperity as follows:

> Five years ago we had begun to feel somewhat encouraged regarding the beneficial effects of purposeful decompressive measures. A paper written on this subject [by me] was quickly followed by the citation at other hands [Frazier] of numerous past cases in which trepanation had served to lessen pre-existing symptoms: the principle, in other words, was an old one . . . but I am unaware that any author had previously suggested a purposeful decompression irrespective of possible tumor removal, and the utilization not only of a 'silent' area but also of overlying muscle to prevent too great protrusion of the herniating brain, or had ever emphasized the importance of decompressing at a distance from the growth as a preliminary measure should the brain prove to be under great tension.

Between 1905 and 1910 we find no less than six papers published by Cushing on decompressive operations, with frequent additional references to these operations in other papers on neurologic surgery; during the same period seven articles were written by Frazier on the same subject. A careful study of the bibliographies of both men for the same 5 year period reveals an amazing vacuum in regard to reports of brain tumors located and directly attacked. In a report by Cushing (85) in 1910 on "The Special Field of Neurosurgical Surgery: Five Years Later," we find that, while he mentions only one patient from whom a brain tumor was successfully removed, he reports that some 80 patients suffering from brain tumor had been seen in his clinic up to October, 1909 and that some 250 operations had been performed on those patients "including such . . . measures as subtemporal decompression." Knowing Cushing's love of "firsts" and his penchant for statistical analysis and reporting, particularly of successful results, one may conclude that there were relatively few brain tumors exposed and directly attacked during this 5 year period from 1905 to 1910. Similarly, a careful reading of all of Frazier's publications between 1903 and 1910 yields reference to only 7 cases in which he had exposed a tumor and made an attempt to extirpate it, although he does refer in 1906 (179) to "some 50 craniotomies," most of them presumably being palliative decompressions.

These figures reflect two facts regarding neurosurgery at that period: (1) the difficulty of locating tumors, and (2) the high mortality attending direct attack on those exposed. It was undoubtedly for these reasons that so much attention was given during those early years (1905 to 1910) to "palliative decompressions."

Brain Tumors

After disposing of the problem of trigeminal neuralgia and developing a satisfactory temporary decompressive operation, Cushing and Frazier were at last free to focus their energies upon the problem of directly exposing and extirpating brain tumors.

In this particular field Frazier (443) appears to have had a slight head start, for as early as 1903 we find him reporting 5 cases in which he had exposed and attempted extirpation of intracranial tumors, with one successful tumor removal. In 1904 (177) he reported a sixth case of considerable importance. It concerned a little boy from whom he removed, through a unilateral suboccipital craniotomy, almost one entire cerebellar lobe as a step in the successful extirpation of a cerebellar tumor. Speaking of this in his report, Frazier says:

> One of the most interesting features of this case . . . is the *comparative impunity with which so large a proportion of the cerebellar hemisphere may be removed.* In this, as in other cases which have come under my observation, not only has there been no marked shock or depression attending the operation but no demonstrable disturbance of function. . . .

In 1908 Frazier reports in collaboration with Mills (323) the removal of a large simple cyst

from the right occipital region of a seventh patient who made an excellent recovery. These 7 cases are the only cases of brain tumor (other than pituitary tumors which we will deal with later on) reported by Frazier between 1905 and 1920! Frazier certainly operated upon a great many tumors during these years, but the paucity of his reports on operations for brain tumor, his failure to submit any statistical data about results, and his failure to make any basic contributions to either the pathology or the treatment of brain tumors (other than pituitary tumors) during this greater than 15 year period is surprising and can only indicate that his principal interests in neurosurgery lay elsewhere than with brain tumors.

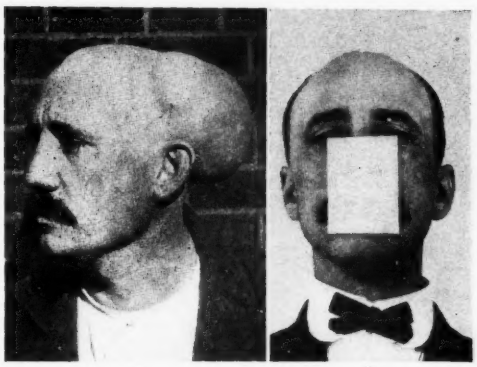
Cushing got a later start than Frazier in his surgery of brain tumors. In his 1905 article on "The Special Field of Neurological Surgery" (72) he was rather "foxy" in that part of his report dealing with the treatment of brain tumors, citing no case records or statistics and disposing of the entire subject with the following:

> In the earlier days of cranial surgery . . . lesions in the motor area of the cortex were about the only ones that were considered approachable, and when we realize . . . [that the surgeon was] guided solely by calculations of the Rolandic area made on the scalp . . . [and] attempted to disclose underlying growths . . . through . . . small trephine openings—it was little wonder that failures were almost universal. Today the reports of successful extirpation are becoming more and more frequent . . . even of growth from situations which a few years ago were considered inaccessible.

It is rather amusing therefore to find in a paper published by him in 1910 (84) these words:

> Five years ago [i.e., 1905] tumor cases were few and far between in the Johns Hopkins Clinic, and though at that time there had been *no*[!] successful extirpations, we had begun to feel somewhat encouraged.

In 1908 Cushing (472) reported removal of a subcortical cystic tumor under local anesthesia which significantly was the only case of extirpation of a tumor cited by Cushing (79) in his 259 page chapter on "Surgery of the Head" in Keen's "System of Surgery" (1908). In 1908 Frazier (323), collaborating with Mills, published a report of one successful extirpation of a simple serous cyst from the occipital lobe of a woman with good recovery, and after that no more case reports of tumor extirpation or statistical reviews of tumor removal by him appeared until after the year 1920.



a b

FIG. 15. Illustrating two types of palliative decompressive operations:

a, In this patient the decompressive openings made in the bone and dura were covered over only by scalp. The photograph shows the size and condition of the hernia a year after operation.

b, In this patient, who had a subtemporal decompression performed by Cushing, the decompressive openings in the bone and dura were placed beneath the right temporal muscle. The patient 2 years after operation.

The years between 1905 and 1908 must have been rather discouraging ones from the standpoint of locating and removing tumors, as is evidenced by the interest expressed in "palliative decompressive" operations during that time (71, 80,444).

Between 1909 and 1910, however, "something happened," for in January, 1910 Cushing (85) published in *Lancet* a report of 64 cases of brain tumor seen personally by him during the 10 months immediately preceding, in which 84 operations had been performed either by Heuer or himself. In 32 of the 64 patients attempts had been made at radical extirpation of a tumor or evacuation of a cyst, and 16 patients (25% of the entire series) "recovered with more or less permanent restoration of function." In addition to the 23 patients in whom a direct attack upon the lesion had been undertaken, there were 41 patients in whom palliative operations only were performed, with only 3 operative deaths and with 21 patients still alive and able to take care of themselves at the time the report was published. In other words, of the total group of 64 patients, 25 per cent had had their lesions removed "with restoration of function," and an additional 30 per cent had been symptomatically benefited, while only 10 per cent had died.

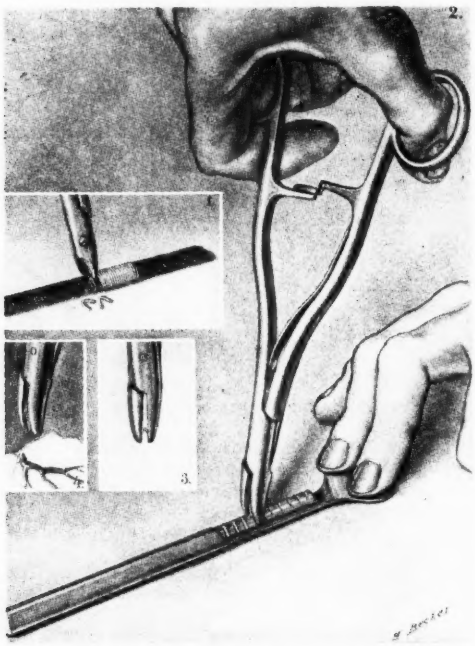


FIG. 16. Drawing to show (*1*) silver wire loops being cut after wrapping on grooved steel pencil; (*2*) one of the clips being picked up from the loaded magazine; (*3*) clip in position in jaws of holder; (*4*) clip placed on meningeal vessel at edge of a dural incision, the empty instrument showing the mould for the clip. (Reduced one-third.)

First published description of the silver clip devised by Cushing in 1911 to control bleeding from blood vessels in the brain. This simple instrument was, in large measure, responsible for the sharp drop in the operative mortality for brain tumors which occurred between 1910 and 1915.

Of special importance, in view of the more or less accepted impression that cerebellar tumors were inoperable, this series of 64 cases included 35 cerebellar operations with 13 successful extirpations of tumor or evacuations of cysts (37.1%); 14 operations abandoned with decompression (40%), with complete abeyance of symptoms in many instances; only 2 cases (5.7 per cent) in which practically no betterment occurred; and only 4 operative deaths (11.4%). Ten months later, in November, 1910, Cushing (84) reported that from October, 1909 to November, 1910 an *additional* 64 patients with brain tumor had been admitted to his service upon whom some 250 operations had been performed!

In 1911 Cushing (86) published a paper of great historical significance on the technical advances in operative surgery. This paper first described the use of silver clips in neurosurgery (FIG. 16). In the same paper Cushing describes the use of muscle stamps for the control of bleeding from the dura, dural sinuses, and brain. With considerable magnanimity Cushing adds that a visitor from Horsley's clinic reported seeing Horsley use muscle stamps to control hemorrhage in his experimental laboratory. However, the most careful search of the literature by the present writer has failed to disclose any report of, or reference to, the use of muscle stamps by Horsley prior to Cushing's 1911 paper. Undoubtedly, the added security against hemorrhage contributed by the use of muscle stamps and silver clips emboldened Cushing to more vigorous attacks on brain tumors, which is reflected in his very remarkable paper, "Concerning the Results of Surgery of Brain Tumors," which appeared in 1915 (90).

TABLE II.—MORTALITY RATES FOR BRAIN TUMOR OPERATIONS AS REPORTED BY CUSHING IN 1915 (90)

Type of case	*Cases observed*	*Cases operated*	*Times operated*	*Operative fatalities*
Supratentorial	55	48	55	4
Hypophyseal	37*	37	42	2
Pineal	4	1	1	0
Cerebellar	32	29	36	5
Pontine	5	4	4	0
Pseudotumors	23	11	11	0
Total	156	130	149	11

*These may be summarized, again, as follows:

	Cases operated	*Operative fatalities*
Subtemporal decompressions	41	0
Osteoplastic craniotomies combined with cerebral decompression	28	3
Transphenoidal operations for hypophyseal tumor	17	1
Suboccipital exploration and decompression	22	3
Suboccipital operations with attempted partial or total removal of the lesion	17	2

The 1915 paper of Cushing's was a statistical analysis of the results of his operations upon 130 patients with brain tumor during the 18 preceding months in which the case mortality was only 8.4 per cent and the operative mortality for the 149 operations was 7.3 per cent (Table II). Cushing in this paper clearly established his preeminence in the surgery of brain tumors by showing his own results to be far superior to those of Horsley (London), Eiselsberg (Vienna), Kuttner (Breslau), and Krause (Berlin), which had been reported in the previous year (90) (Table III). He was especially pleased with his

TABLE III.—COMPARISON OF CUSHING'S OPERATIVE MORTALITY FOR ALL BRAIN TUMORS WITH THAT OF OTHER CONTEMPORARY SURGEONS—1915(90)

Surgeon	*Number of patients*	*Number of operations*	*Mortality (per cent)*
Horsley, *et al.* 1902–1911, incl. (London)	265	—	37.3*
Von Eiselsberg 1903–1913, incl. (Vienna)	168	—	38.0
Kuttner 1908–1914, incl. (Breslau)	104	104	45.0
Krause 1900–1911 (Berlin)	109	109	50.0
Cushing 1913–June 1914 (Boston)	130	149	8.4

*Cushing's own revision of Horsley's figure.

operations on the cerebellar pontine angle (acoustic nerve) tumors; the average case mortality for the 77 tumors of this type operated upon by Horsley, Eiselsberg, and Krause was 72.7 per cent, whereas the case mortality for his own 30 cases was only 13 per cent (Table IV).

Cushing's 1915 report marked the turning point and, indeed, for all practical purposes, victory in the first fierce struggle to overcome the forbidding mortality which had generally attended operations on brain tumors prior to 1905. Two facts about this achievement command our attention. One was the amazing rapidity with which the victory was achieved, less than 10 years having elapsed since Cushing first attempted extirpation of a cerebral tumor. The second was that this was accomplished with very simple "tools": ordinary hemostats for the scalp, wax for the bone edges, muscle stamps for the dura, and silver clips for the brain. More important was the application of the surgical principles given by Halsted to Cushing: fastidious gentleness in the handling of tissue and meticulous hemostasis, which Cushing, in turn, reapplied with a master's skill to neurologic surgery. Above all, however, was an intense concentration of mind and energy upon a single problem.

Here, indeed, was Cushing's answer to the question which he had posed 10 years before: "Are practice of hand and concentration of thought to go for nothing?" No other surgeon, even Cushing himself, has ever been able to significantly lower these mortality figures, even

TABLE IV.—RESULTS OF OPERATIONS FOR ACOUSTIC NERVE TUMORS AS REPORTED IN THE LITERATURE—1915

Surgeon	*Number of cases*	*Case mortality (per cent)*
Horsley *et al*	36	66
Von Eiselsberg	17	71
Krause	24	75
Total	77	
Average		72.7
Cushing		
Attempted extirpation	13	30
Decompression	17	0
Total	30	
Average		13

after ventriculography, mechanical suction, electrosurgery, and the blood bank had been added to the surgeon's armamentarium. Cushing's last reported mortality figure, for the years 1929 to 1931, was, by a remarkable coincidence, *exactly* that which he had reported in 1915 (102), namely, 8.7 per cent (FIG. 21)!

Pituitary Tumors

Concurrently with his attack on brain tumors in general, Cushing had been devoting special attention to a study of the pituitary gland—its physiology and pathology and the possibilities of surgical treatment for its various disorders. This was a subject which was to absorb a large share of his energies and efforts for the remaining years of his active life; indeed, his last great contribution was his description of the basophilic adenoma and its correlation with the clinical syndrome which bears his name.

The first paper on the pituitary gland by Cushing, published in collaboration with Reford (396), was entitled "Is the Pituitary Gland Essential to the Maintenance of Life?" This paper reported hypophysectomies in a series of laboratory animals; some of these animals survived the operation itself, but after a few days they developed progressive cachexia and dysenergia and rapidly died. This led Cushing and Reford to express the opinion in their paper that the hypophysis *was* essential to the maintenance of life. The following year Cushing (84) wrote regarding the pituitary body:

> It has been learned that the anterior lobe of the gland is essential to life . . . [and that] the infundibular lobe is closely bound up with metabolic processes. . . . Despite the demonstration that the sella turcica is accessible, . . . the proven importance to life of the glandular structure which rides in the saddle must breed hesitation in the minds of those who would dis-

FIG. 17. Fourteen days after operation. (To show situation of incision.)

This acromegalic patient with pituitary tumor was the first one on whom Cushing operated. Note the unfamiliar omega-shaped incision over the frontal sinus. A description of this first, but soon discarded, approach to the pituitary gland is given in the text.

lodge it. No one, as yet, would venture to assert that a tumor of the infundibular region can be *totally* removed.

However, in October of the same year experimental studies carried out by Cushing (65) in collaboration with Crowe and Homans demonstrated that laboratory animals could survive *partial* hypophysectomy, and before the ink was dry on that publication we find him reporting a partial hypophysectomy on a man suffering from acromegaly (82). This operation was the first on the hypophysis to be performed by Cushing; its technical features differ in essential features from any subsequent operation by Cushing and hence may be of interest to present day neurosurgeons.

An omega-shaped incision [FIG. 17] was made over the frontal sinus. . . .

With a perforator and burr primary openings were made entering the outer side of each frontal sinus; a communication was made between these openings through which a Gigli saw was passed, and the upper edge of the proposed frontal sinus flap was cut from within outwards. Then . . . the lateral incisions of the proposed frontonasal flap were carried downward through the nasal bones to their inferior margin in correspondence with the original skin incision. The median septa were divided with a few strokes of a thin-bladed chisel and the flap, consisting of anterior wall of the frontal sinus with the divided nasal bones and overlying soft parts, was broken loose and reflected downward. . . .

The ethmoidal cells were then carefully rongeured away until a mesial channel possibly 2 cm. in diameter was made just below the ethmoidal roof and carried well back toward the posterior part of the nasal fossa. A head-light was then employed and the position of the sphenoidal cells easily determined. Their anterior wall was broken down, and on the upper and posterior aspect of their cavity the characteristic median projection of the sella turcica into these sinuses was easily detected. The thin shell of bone was chipped away with delicate strokes of a narrow chisel, exposing the spherical pocket of dura which envelopes the gland. This dural pocket was very tense and, judging from our experiences on the cadaver, was somewhat larger than normal. It was incised longitudinally and a considerable portion—possibly one-half of the exposed gland—was removed piecemeal with the aid of a delicate, long-handled curette. . . .

The patient returned to his home on a farm in the West.

Perhaps no single incident in Cushing's surgical career better shows his power of concentration and the vigor of his attack upon any subject than the fact that within less than 2 years after his first operation upon a hypophyseal tumor he had published his beautiful and classic monograph on "The Pituitary Body and Its Disorders" (87). This was an intimate and detailed study of some 49 patients with disturbances of

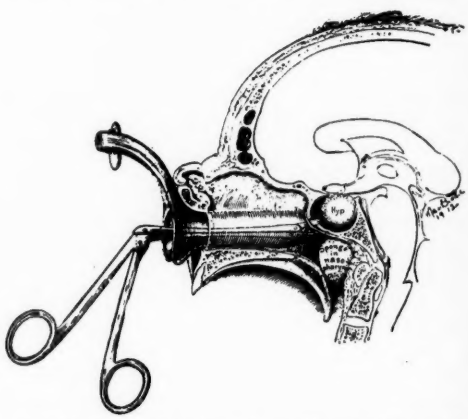


FIG. 18. Cushing's endonasal transphenoidal operation for removal of pituitary tumors. He employed this approach almost exclusively from 1910 until 1925.

the pituitary body of whom 43 had been operated upon by Cushing. Fourteen of the patients, principally the earlier ones, had received only subtemporal decompressions, but in 29 of these patients the tumor had been attacked directly, with only 4 deaths attributable to the operation, an operative mortality of 13.7 per cent. Two years later (1914) Cushing (89) published the results of 74 operations for tumors of the hypophysis performed by him on 68 patients with only 7 deaths, an operative mortality of 9.5 per cent, and in 1927, 300 operations, with a mortality of only 4 per cent (98).

In all of these cases, excepting a very few of his earliest ones, Cushing employed what he repeatedly referred to as "the favored transphenoidal operation" (FIG. 18). The history of the gradual evolution of this *extracranial* operation is fascinating to read, but space will not permit its retelling here[10]. Special attention, however, must be given to Hirsch, a rhinologist of Vienna, who in 1909 (228) proposed an intranasal, transphenoidal approach to the pituitary gland; he performed his first endonasal operation without reflection of the nose on March 10, 1910 (229) and by a curious coincidence did his first endonasal, submucous approach to the pituitary gland on the precise day (June 4, 1910) that Cushing did his first sublabial incision and submucous resection of the septum. In 1911 (230) Hirsch reported 12 cases in which he operated with 2 deaths and in 1912 (231) 26 cases with 3 deaths (11.5%), and in 1926 (232) he stated that he had operated in 100 cases by his method, but he did not report his results.

In the early part of 1913 Frazier (183) described a transfrontal, intracranial approach to the hypophysis (FIG. 19) through which he had successfully evacuated a pituitary cyst, and later in the same year he reported on a total of 4 patients with pituitary lesions which were evacuated or extirpated by this same method with no fatalities (184). In this paper Frazier gives a report of all the operations upon the hypophysis which he had been able to collect from the literature up to that time, and his findings are reported in Tables V and VI. He notably has failed to "find" the 29 cases reported by Cushing in 1912 (87)! The present writer has briefly reported these, together with additional cases which Cushing reported in 1914 (89) in Table VII, following the style of Frazier's tables for easier comparison of the results.

[10]The interested reader is urged to refer to the excellent and richly illustrated account given by Walker (490).

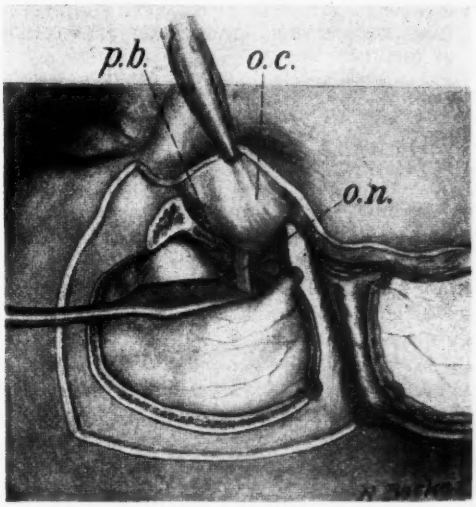


FIG. 19. Frazier's intracranial subfrontal extradural approach to the hypophysis first described by him in 1913. Two years later, however, he abandoned his intracranial approach for the popular endonasal transphenoidal operation of Cushing.

TABLE V.—RESULTS OF OPERATIONS FOR PITUITARY TUMORS ACCORDING TO TYPE OF OPERATION COLLECTED FROM THE LITERATURE BY FRAZIER IN 1913 (184)

Result	*Extracranial (endonasal transphenoidal)*	*Intracranial (transfrontal)*	*Temporal decompression*	*Total*
Death	24	2	3	29
Improved beyond 2 years	5	–	–	5
Improved with relapse	2	–	–	2
Temporarily improved	31	5	–	36
Unimproved	2	–	–	2
Total	64	7	3	74

TABLE VI.—RESULTS OF OPERATIONS FOR PITUITARY TUMORS ACCORDING TO SURGEON COLLECTED FROM THE LITERATURE BY FRAZIER IN 1913(184)

Surgeon	*Number of cases*	*Operative mortality (per cent)*
All operators	74	39.1
Eiselsberg	16	25.0
Hirsch	14	21.4
Frazier	4	0.0

TABLE VII.—OPERATIVE MORTALITY FOR PITUITARY OPERATIONS (ENDONASAL) PERFORMED BY CUSHING

	Number of cases	*Operative mortality (per cent)*
Cushing		
1912 series(87)	29	13.7
1914 series(89)	68	9.5

The intracranial (transfrontal) operation was undoubtedly the first in the field, but it did not prove successful in the hands of surgeons untrained in neurologic surgery. For most surgeons it was attended by failure to expose the lesion, by massive hemorrhage, or by severe injury to the brain. While the transphenoidal operation is not always technically easy, it is inherently safer from the standpoint of hemorrhage and brain injury than the intracranial operation, and can more readily be performed without special knowledge of, or special training in, neurosurgery; for this reason it early became the operation of choice for hypophysial tumors, and through various modifications and refinements (490) it evolved into the highly perfected inferior nasal, sublabial operation of Cushing.

From approximately 1912 until 1928 or 1930 the transphenoidal operation was the method of choice and almost universally used. Cushing, in his 1912 monograph on "The Pituitary Body and Its Disorders" (87), referred to it no less than 29 times as "the favored transphenoidal operation," and as late as 1927, in a paper presented before the Medical Society of London (99) in which he reported "some 300 odd operations" upon the pituitary gland with a mortality rate in the neighborhood of only 4 per cent, he mentioned *only the transphenoidal route*. It is also interesting that Frazier, who first described and employed a transfrontal intracranial approach to the hypophysis in 1913 (183) and stated at that time his opinion that "in the future preference would be given the intracranial route through the anterior cranial fossa," in 1915, just 2 years later (185), stated:

> The surgery of pituitary lesions in my clinic has resolved itself largely into the invasion of the sella turcica by the *transphenoidal endonasal route*. This operation we have resorted to now *routinely* for the past two years.

However, by 1929 Cushing had begun to alternate between the transphenoidal and the transfrontal operation. A year or two after that he had almost entirely replaced the transphenoidal by the transfrontal intracranial operation. This swing to the transfrontal operation coincided with the publication by Cushing of his important paper on "The Intracranial Tumors of Preadolescence" (96), with stress on the craniopharyngiomas, and of his very important paper on "Meningiomas Arising from the Tuberculum Sellae" (109) (FIG. 20). These two tumors might easily be missed entirely and, if found, could only be poorly handled with the transphenoidal operation. Since about 1930, with the general indoctrination of the oncoming generations of neurosurgeons in Cushing's careful operative techniques, there has taken place a growing trend away from the endonasal, and toward the intracranial, operation; today the latter is almost universally used.

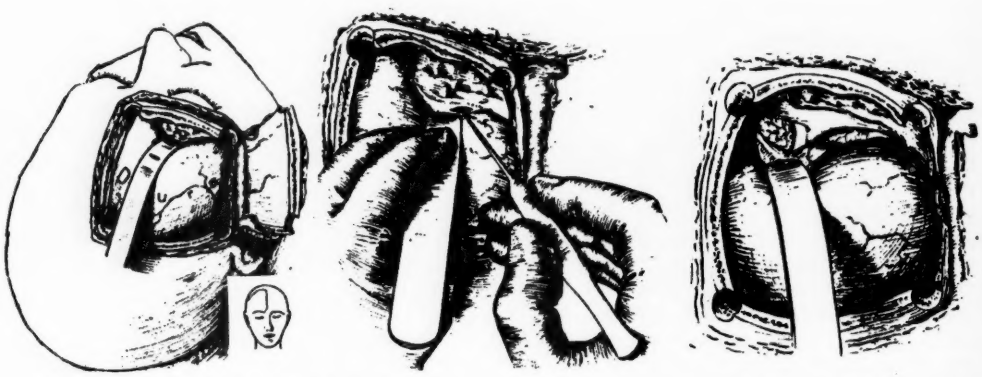


FIG. 20. Cushing's later intracranial transfrontal approach to the pituitary gland and parachiasmal region. He developed this approach about 1927 after his description of meningiomas arising from the tuberculum sellae.

Acoustic Neurinomas

Having disposed of pituitary tumors for the time being, or at least having established a temporary bridgehead on this front, Cushing like a seasoned field general quickly turned his attack in other directions—to the cerebellar tumors and particularly to tumors of the nervus acusticus. Before Cushing and Frazier appeared upon the scene, operations upon tumors of the posterior fossa had been accompanied by a prohibitive mortality; among the 55 cerebellar operations which had been collected from the literature by Knapp (267) before 1905 there had been a 45 per cent operative mortality, and these tumors were considered by most commentators to be practically inoperable. In 1909 Cushing (83) reported 34 operations performed in the posterior fossa for the removal of verified or presumed tumors, with only 2 operative deaths (6% mortality). In 13 of these cases the lesion was exposed and the solid tumors were extirpated and the cystic tumors were evacuated; in the remaining 12 cases, in which tumors were not found, decompressions were performed without any fatalities. In 1910 (85) in the *Lancet*, he reported, ". . . in a group of 35 cerebellar operations there have been 4 operative fatalities (11.4%), 13 successful extirpations or cyst evacuations (37.1%), 14 simple decompressions (40%) with complete abeyance of symptoms in many instances." This is in striking contrast to the prevailing results as reported by Oppenheim (85), who collected from the literature 27 operations "performed by skillful surgeons in selected cases" during the preceding 3 years, with a 50 per cent operative mortality, and only 2 (3%) of the patients could be regarded as having had a favorable result from the operation.

By 1915 Cushing (90) had already begun to concentrate on cerebellar pontine angle tumors (tumors of the nervus acusticus), as distinguished from the other tumors in the posterior fossa, and in that year published his own results in 30 operations for removal of these tumors, along with the results reported from other leading clinics for comparison.

In 1917 Cushing (91) culminated this particular "drive" by the publication of a second classic monograph, entitled "Tumors of the Nervus Acusticus." In this magnificent monograph, which followed in general format his earlier monograph on the pituitary body and its disorders (87), Cushing reported in great detail and with beautiful illustrations the histories of 29 verified acoustic neurinomas, together with detailed statistical analyses of his results. Once again his low operative mortality in these difficult cases was in the sharpest contrast to the mortality which prevailed everywhere else in the world and gave Cushing a commanding position of pre-eminence in this particular field. His results, compared with those of his contemporaries, are given in Table VIII in condensed form. Note that in general throughout the world (even in 1917) the mortality rate for attempted extirpations of tumors of the nervus acusticus was in the neighborhood of 75 per cent, whereas Cushing's mortality for his Boston series of 18 patients operated upon between 1912 and 1917 was only 11 per cent (91).

TABLE VIII.—RESULTS OF OPERATIONS FOR ACOUSTIC NERVE TUMORS AS REPORTED IN THE LITERATURE—1917(91)

Surgeon	*Number of cases*	*Operative mortality (per cent)*
Henschen (collected cases, 1910)	43	80
Leischner (1911)	10	70
Krause (personal cases, 1912, reported by Fumarola)	30	86.6
Eiselsberg (1912)	12	66.6
Horsley *et al.* (1912, reported by Tooth)	24	70
Henschen (collected cases, 1910–1915)	70	68.7
Cushing (personal cases)		
Baltimore series (1902–1912)	11	35
Boston series (1912–1917)	18	11

In November, 1920 Cushing (92), in remarks at a meeting held at the Peter Bent Brigham Hospital, reported final statistics in 47 cases of acoustic nerve tumors with end results and pointed out that among the last 19 consecutive patients operated upon by him there was only one surgical death, bringing his operative mortality for this most difficult surgery down to 5.3 per cent!

What a tremendous distance had been covered in 15 short years! In 1905 the mortality for brain tumor operations was approximately 30 per cent (267); in 1920 we find the mortality figures not only for brain tumors in general but for the more difficult hypophysial and cerebellar pontine angle tumors well stabilized in the neighborhood of 10 per cent or less. This had been accomplished almost single-handedly by Cushing.

There remained for Cushing to contribute one final great technical advance to neurosurgery—the introduction of electrosurgery. En-

COMPARISON OF MORTALITY PERCENTAGES FOR COMPLETE SERIES AND PAST THREE YEARS

	Entire series (30 years) 1901–1931						*New cases (3 years) 1928–1931*				
Verified tumours	*No. pts.*	*Pts. op. on*	*No. ops.*	*P.o. deaths*	*Case-mort. per cent*	*Op. mort. per cent*	*No. pts.*	*No. ops.*	*P.o. deaths*	*Case-mort. per cent*	*Op. mort. per cent*
I. Gliomas (varia)	62	780	1,173	202	25.9	17.2	198	282	31	15.7	11.0
II. Pituitary adenomas	360	349	403	25	7.1	6.2	59	70	4	6.8	5.7
III. Meningiomas	271	260	489	54	20.8	11.0	69	103	8	11.6	7.7
IV. Acoustic tumours	176	171	219	25	14.6	11.4	41	45	2	4.9	4.4
V. Congenital tumours (varia)	113	106	160	23	21.7	14.4	17	25	4	23.5	16.0
VI. Metastatic and invasive	85	63	80	18	28.6	22.5	10	11	4	40.0	36.4
VII. Tuberculomas and syphilomas	45	40	49	15	37.5	30.6	4	5	0	0.0	0.0
VIII. Blood-vessel tumours	41	37	59	6	16.2	10.2	7	10	1	14.3	10.0
IX. Sarcomas (primary)	14	12	17	6	50.0	35.3	0	0	0	—	—
X. Papillomas	12	11	23	3	27.3	13.4	1	2	0	0.0	0.0
XI. Miscellaneous	44	41	63	5	12.2	7.9	6	9	1	16.6	11.1
Total	2,023	1,870	2,735	382	20.4	13.9	412	562	55	13.3	9.8
Unverified tumours	859	496	557	12	2.4	2.2	66	73	0	0.0	0.0
Grand total	2,882	2,366	3,292	394	16.6	11.9	478	635	55	11.5	8.7

FIG. 21. Cushing's operative mortality in a series of 2,023 verified brain tumors. The table is taken from his monograph published in 1932 on "Intracranial Tumors."

couraged by him, Bovie developed "a new electrical current generator" (which we now know as the Bovie electrosurgical unit) and in 1928, with Bovie personally supervising the operation of his machine, Cushing (108) first used the instrument in a brain operation.

Electrosurgery has proved a great boon to the neurologic surgeon not only in speeding the control of bleeding vessels but especially in permitting the piecemeal removal of the meningiomas. As a result of this final technical contribution, Cushing was able by 1932 to reduce the mortality figures for all types of tumors still further (105) (FIG. 21), concluding the first and basic phase in the evolution of neurosurgical techniques.

Pneumoventriculography

We must now turn backward in our narrative a few years to 1918 when an event occurred which had an incalculable effect on the development of neurosurgery. It was in that year that Walter E. Dandy (114) (FIG. 22) first described a method for visualizing the cerebral ventricles by replacing the intraventricular fluid with gas, and gave to the world ventriculography (FIG. 23). His own description of how this came about makes interesting reading:

> For some time I have considered the possibility of filling the cerebral ventricles with a medium that will produce a shadow in the radiogram. If this could be done, an accurate outline of the cerebral ventricles could be photographed with X-rays, and since most neoplasms either directly or indirectly modify the size or shape of the ventricles, we should then possess an early and accurate aid to the localization of intracranial affections. In addition to its radiographic properties, any substance injected into the ventricles must satisfy two very rigid exactions: (1) it must be absolutely non-irritating and non-toxic; and (2) it must be readily absorbed and excreted.
>
> The various solutions and suspensions used in pyelography—thorium, potassium, iodide, collargol, argyrol, bismuth subnitrate and subcarbonate, all in various concentrations—were injected into the ventricles of dogs, but always with fatal results, owing to the injurious effects on the brain. . . .
>
> Ventriculography, therefore seems possible only by the substitution of gas for cerebrospinal fluid. It is largely due to the frequent comment by Dr. Halsted on the remarkable power of intestinal gases "to perforate bone" that my attention was drawn to its practical possibilities in the brain. Striking gas shadows are present in all abdominal and thoracic radiographs. The stomach and intestines are often outlined by the contained air, even more sharply than when filled with bismuth. A small collection of gas in the intestines often obliterates the kidney outlines. A perforation of the intestines may be diagnosed by the shadow of the air that has accumulated under the diaphragm. . . . The paranasal sinuses and mastoid air cells show up in a thick skull by virtue of the air. . . . From these and many other normal and pathological clinical demonstrations of the radiographic properties of air it is but a step to the injection of gas into the cerebral ventricles—pneumoventriculography.

In the following year Dandy (115) described visualization of the ventricles of the brain following the injection of air into the lumbar subarachnoid sac, that is, pneumoencephalography.

Pneumoroentgenology of the cerebral ventricles made accessible to direct surgical attack fully 30 or 40 per cent of the intracranial tumors which previously had been unlocalizable by any clinical method of examination and in addition provided a technique for investigating any num-

ber of intracranial conditions other than brain tumors, such, for example, as hydrocephalus.

Hydrocephalus

Although ventriculography is the contribution which first made Dandy's name generally known to the surgical world, it was not by any means his first serious contribution to neurologic surgery. As early as 1913 (138) he began, in collaboration with K. D. Blackfan (then Professor of Pediatrics at the Johns Hopkins Medical School), a long-term program of experimental and clinical studies of internal hydrocephalus.

Their first paper (1913), which was presented as a preliminary report, included observations on dogs after the production of experimental hydrocephalus, together with observations on patients suffering from the disease. In these experiments an obstruction was placed in the aqueduct of Sylvius, thus occluding the only way of exit for the cerebrospinal fluid from the third and the lateral ventricles. Internal hydrocephalus invariably resulted due to this purely mechanical obstruction in the aqueduct.

Since the venous obstruction was considered a possible cause of hydrocephalus, a series of experiments was conducted in which the vein of Galen and the straight sinus were ligated. In none of these did hydrocephalus result. It was shown that less than 1 per cent of the dye injected into the ventricles was absorbed in two hours, whereas up to 60 per cent injected into the subarachnoid space was absorbed in the same period. This demonstrated that the absorption of cerebrospinal fluid takes place almost entirely in the subarachnoid space. Further experiments indicated that cerebrospinal fluid passed directly into the blood and that lymphatic channels were not concerned in its absorption.

It was subsequently shown that the pacchionian granulations do not play any special role in the absorption of the fluid. After a suitable dye was injected into the spinal subarachnoid space, the cerebral subarachnoid space being closed, there was found to be a quantitative absorption proportionately as great as from the entire subarachnoid space; this shows that the cerebrospinal fluid was absorbed by a diffuse process from the *entire* subarachnoid space, both cerebral and spinal, and that its absorption was not restricted to any special locality as, for instance, the region of the venous sinuses or the pacchionian granulations. It was further shown that practically no absorption took place in the ventricles.

Facts were elicited demonstrating the secretory rather than the mechanical formation of the cerebrospinal fluid within the ventricles.

When phenosulphonephthalein was injected into the cerebral ventricles, it normally appeared in the lumbar spinal fluid of the animals within 2 to 3 minutes. By use of the dye test it was possible to establish *two types of hydrocephalus*. In the first type, where there was an obstruction within the ventricular system, after the injection of phenosulphonephthalein into the ventricles its appearance in the lumbar spinal fluid was greatly delayed; in the second type, where communication between the ventricles and the subarachnoid space, the dye injected into the ventricles appeared promptly in the lumbar spinal fluid.

FIG. 22. Walter E. Dandy.

The following year the same authors (139) published a superb report containing all of their

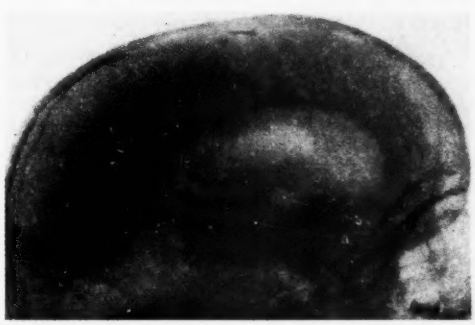


FIG. 23. Pneumoventriculography was first described by Dandy in 1918. The roentgenogram shown above is the first published ventriculogram appearing in Dandy's original report.

Prior to ventriculography 30 to 40 per cent of intracranial tumors could not be localized by clinical means. Following the introduction of this great diagnostic aid, practically 100 per cent of all intracranial tumors could be accurately localized.

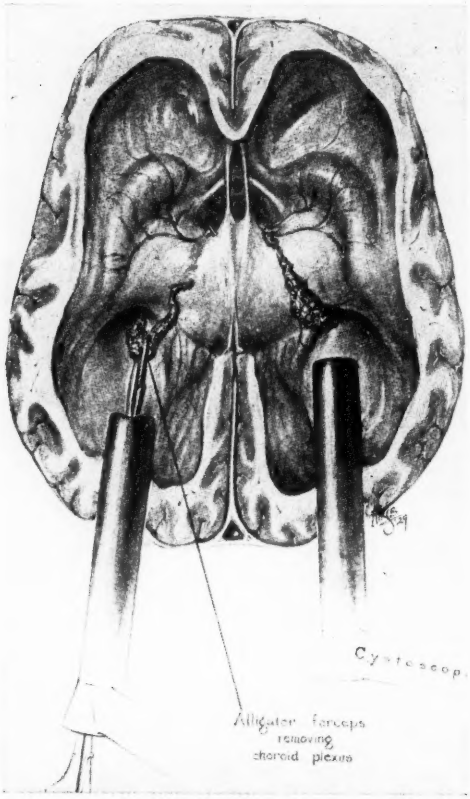


FIG. 24. Extirpation of the choroid plexus for the treatment of nonobstructive (communicating) hydrocephalus as described by Dandy in 1918.

The rationale for the operation was sound, but the operation was technically bad for the reason that it required drainage of the ventricular fluid which, in turn, allowed collapse of the thinned-out cortex, resulting in severe neurogenic shock and vasomotor collapse. Dandy reported only 4 cases of children operated upon by this method, with 1 survival.

Endoscopic techniques developed 15 years later utilized Dandy's sound surgical principle but corrected the technical deficiencies inherent in his original operation.

experimental data supplemented with extensive clinical observations to substantiate, in the human being, the observations which they had made in the laboratory. These two papers supply the basic groundwork for all subsequent studies of hydrocephalus.

Following these two reports came an important series of clinical and surgical papers on the subject of hydrocephalus from Dandy's pen. In 1918 (113) he described an operation for treating *nonobstructive* hydrocephalus by excision of the choroid plexuses from the lateral ventricles (FIG. 24), and reported 4 children who were operated upon by this method with one survival. Dandy also first saw and enunciated the fundamental principle that in the treatment of *obstructive* hydrocephalus due to atresia of the aqueduct of Sylvius the ventricular fluid must be rerouted into normal cerebrospinal fluid channels. Acting on this principle he (117) devised an operation for treating obstructive hydrocephalus by establishing an opening between the hypothalamic portion of the third ventricle and the interpeduncular (subarachnoid) cistern, whence it could be distributed directly out over the cerebral cortex in normal subarachnoid spaces, and there absorbed by natural processes. This was the first "third ventriculocisternotomy" or "third ventriculostomy" (FIG. 25); he employed this method six times, making no claim for its success.

By clarifying the pathological difference between obstructive (noncommunicating) and nonobstructive (communicating) hydrocephalus, by devising a simple test for differentiating clinically between the two types, and by providing rational surgical principles and operations for treating each type ("third ventriculostomy" for the obstructive type and "choroid plexectomy" for the nonobstructive type), Dandy paved the way to the solution of this old, old problem. Curiously, however, after having done all this, Dandy seemed suddenly to lose interest in the subject; his one patient who survived choroid plexectomy was for years his only reported case of hydrocephalus successfully treated.

Acoustic Neurinomas—Total Removals

By a curious coincidence, in the very year (1917) that Cushing published his classic monograph "Tumours of the Nervus Acusticus," in which he made the following statement: "I doubt very much, unless some more perfected method is devised, whether one of these tumors can safely be totally enucleated," Dandy (112) presented before a local meeting of the Johns Hopkins Medical Society a patient from whom he had successfully extirpated in toto a tumor of the nervus acusticus while his surgical chief, Dr. Heuer, was out of town. This trick of fate seemed to fire Dandy with a special zeal to outdo Cushing in the latter's own special domain, as he later wrote: (136)

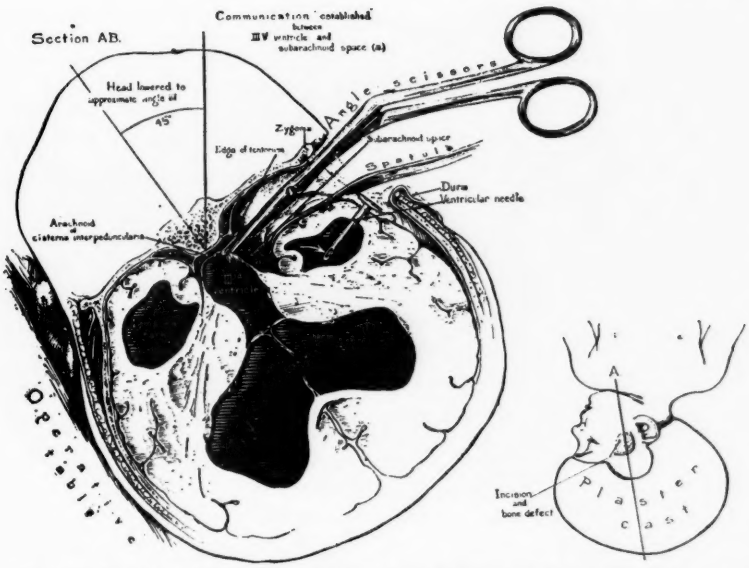


FIG. 25. Dandy's "third ventriculostomy" for the treatment of obstructive (noncommunicating) hydrocephalus.

Dandy, in 1922, was the first to point out that rational treatment of obstructive (noncommunicating) hydrocephalus demanded drainage of the cerebrospinal fluid from the obstructed ventricles into a subarachnoid space whence it could be absorbed by natural processes. He accomplished this by establishing an opening between the third ventricle and the interpeduncular cistern.

The above figure illustrates Dandy's final modification of his original technique. Dandy reported using this operation 6 times but made no claim for its success.

It [seemed] incredible that a perfectly benign, encapsulated, not-too-firmly-fixed tumor that was potentially curable should present an insoluble problem. The solution came from a realization of the underlying causes of failure and their avoidance. The one important cause of death was injury to the brain stem, and it was then learned that by painstaking dissection of the capsule of the tumor after the interior had been scooped out by successive applications of a curette, trauma to the brain stem could be reduced to a degree compatible with preservation of life and function.

In 1922 Dandy (118) reported two more successful total removals of acoustic nerve tumors, and in 1925 (121) he reported 17 cases in which the tumor had been totally removed, but with 7 deaths; however, in 12 of these cases the tumor had been shelled out with the finger and all of the 7 deaths occurred in this group; in the 5 cases in which the capsule had been carefully dissected away from the pons there were no deaths. In 1934 Dandy (133) described an operation for the removal of acoustic nerve tumors through a unilateral approach, but did not give any statistical results for this modification. In 1941 (136) he reported the total removal of 46 acoustic neurinomas by the unilateral approach with only 2 deaths, an operative mortality of 10.8 per cent.

After Dandy first demonstrated that total removal of acoustic nerve tumors, with permanent cure, could be accomplished with an operative risk not much greater than for incomplete removal, other neurosurgeons began to follow his lead and perform the radical operation. In 1934 Olivecrona (345) reported a series of 31 acoustic nerve tumors which he had totally removed following Dandy's technique with an operative mortality of 19.4 per cent. These results were very much better than those he had previously obtained with the partial intracapsular operation of Cushing, namely, 34 cases with a 27.7 per cent operative mortality, and an additional case mortality of 35 per cent within 3.5 years.

In 1939 Horrax and Poppen (239) reported total extirpation of 35 acoustic nerve tumors

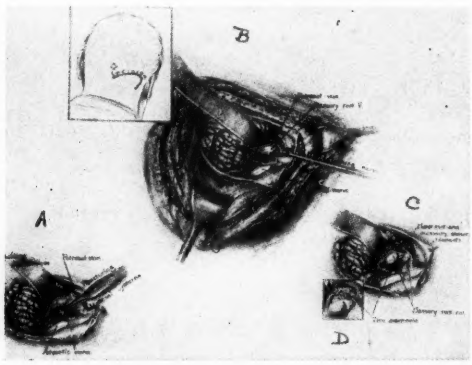


FIG. 26. Dandy's operation for relief of trigeminal neuralgia. In 1925 he described a unilateral suboccipital approach with section of the sensory root of the nerve alongside the pons.

with an operative mortality of 17.8 per cent. However, 12 of these patients had previously been operated upon elsewhere and the operative difficulties and risks were abnormally high in these patients. In the 23 patients operated upon first by the authors the mortality was only 8.7 per cent.

In 1949 Givre and Olivecrona (207) reported from the latter's clinic the immediate and late results of 300 operations for the removal of acoustic nerve tumors. In 83 of the earlier cases intracapsular enucleations with incomplete removal of the tumor had been performed and the operative mortality was 29 per cent; among those surviving there was recurrence in 50 per cent of the cases within 3 or 4 years, which led to death or to a second operation; the mortality rate for the second operation was 40 per cent of those surviving the first operation. In 217 cases the tumor was completely removed with an operative mortality of 23.5 per cent, in about 30 per cent of the cases the anatomical continuity of the facial nerve was preserved, and in about two-thirds of these there was a good or satisfactory return of function.

While the operative mortality accompanying total removal of acoustic nerve tumors has never been brought down to equal the phenomenally low figure attained by Cushing with his partial, intracapsular removal in his last 50 cases (4%), nevertheless it has been brought down to comparable levels (10.8%) by Dandy, and even lower (8.7%) by Horrax and Poppen. Survival after operation, however, is not the only consideration in evaluating the operative results. As reported by Cairns (45), among 10 patients who had had intracapsular removal of the tumor by Cushing while Cairns was associated with Cushing, there were 8 survivors after an interval of 9 years, but only 3 were able to work, 2 had considerable disturbance of gait, and 3 were severely incapacitated. Givre and Olivecrona (1949) further pointed out that 50 per cent of their patients who had had the intracapsular operations had either died or had been reoperated upon within 3 to 4 years with a 50 per cent mortality attending the second operation.

As a result of these experiences there has occurred in recent years an increasing trend among the majority of neurosurgeons toward the radical (total) removal of acoustic nerve tumors.

Surgery of the Fifth, Eighth, and Ninth Cranial Nerves in the Posterior Fossa

Dandy's preoccupation with the cerebellar pontine angle tumors and his amazing skill in this sensitive field undoubtedly accounted for his three interesting contributions which followed, namely, (1) section of the sensory root of the fifth cranial nerve at the pons for relief of trigeminal neuralgia, (2) section of the eighth cranial nerve for the relief of Menière's syndrome, and (3) section of the ninth cranial nerve for relief of glossopharyngeal neuralgia.

Division of the sensory root of the trigeminus, alongside of the pons (FIG. 26), for the relief of trigeminal neuralgia was first described by Dandy in 1925 (126), who reported its successful use in 2 patients. In 1929 (127) he published a comprehensive report of his method with case records of 23 patients successfully operated upon by the posterior route. Dandy claimed that his operation eliminated keratitis, facial paralysis, risk of cutting the trigeminal motor root fibers, and postoperative paresthesias, but Frazier (188) questioned that it had these advantages.

In 1861 Menière (312, 313, 314) described the syndrome of vertigo, tinnitus, and loss of hearing as a clinical entity; this syndrome now bears his name. He suggested its relationship to the labyrinth. In 1874 Charcot (53, 54) noted that when a patient with Menière's syndrome became completely deaf the attacks of vertigo often ceased, and he suggested that the auditory nerve might be divided in this condition. However, surgery was not then sufficiently advanced for such an operation.

The first intracranial section of the eighth nerve for "painful tinnitus" (Menière's syndrome) was performed by Ballance (20) in 1908, with a good result. In 1912 Frazier (182), at the suggestion of Mills, sectioned the nerve for "aural vertigo," but obtained only partial relief from the symptoms.

After Frazier's operation in 1912 no new reports of intracranial section of the eighth nerve for Menière's syndrome appeared in the literature until 1928 when Dandy (126) published an important paper dealing with this subject.[11] After acknowledging Frazier's priority in performing the operation and expressing the opinion that Frazier's failure to obtain relief was due to a mistaken diagnosis of Menière's syndrome, he (126, 131) then reported case histories of 9 patients with true Menière's syndrome who had been operated upon by him, with complete relief from vertigo but with only "moderation" of the tinnitus. Crowe (65), later in the same year, reviewed Dandy's cases and showed that the tinnitus had not been decreased by Dandy's operation, and, largely as a result of his report, section of the eighth nerve for tinnitus alone has been discarded.

In 1931 McKenzie (302) performed the first *differential* section of the eighth nerve; that is, section of the vestibular portion only with preservation of the cochlear portion. McKenzie's description of the variations in the normal anatomy of the seventh and eighth nerves and the adjacent structures and his description of the technique for isolating the vestibular component of the eighth and seventh nerves are beautifully illustrated and are exceptionally valuable. Dandy later adopted McKenzie's technique; he also modified his original operation in several ways, operating with the patient in the lateral position rather than in the prone position and sectioning the nerve with electrocautery rather than with scissors (134). Cairns and Brain (46) reported a series of eighth nerve sections in 1933 and were enthusiastic about their results, although several patients died as a result of the operation. Olivecrona (346) in 1938 reported treating 160 patients; Ray (393) in 1948 reported another series of cases. In 1951 Castellano (49) published a report on 300 patients with Menière's syndrome studied in Olivecrona's clinic, of whom 254 were operated upon. There was no operative mortality; facial paralysis occurred in 16 patients, but was permanent in only 2. Complete freedom from dizziness was attained in all patients except 8, 7 of whom had bilateral Menière's syndrome. Tinnitus, on the other hand, rarely disappeared.

The glossopharyngeal nerve was first sectioned intracranially by Fay (155), in 1926, along with the trigeminal root and the upper cervical posterior roots for the relief of pain caused by an inoperable carcinoma of the throat. In 1927 Dandy (123) was the first to cut the ninth cranial nerve intracranially for the relief of true glossopharyngeal neuralgia.

Surgery of the Third Ventricle

The first successful removal of a *pineal tumor* was apparently performed by Krause and reported by him and Oppenheim (351) in 1913; he used a posterior fossa approach. In 1921 Dandy (116) devised an approach to the pineal locality similar to that used by him in the experimental removal of pineal glands in laboratory animals: a large right parieto-occipital flap extending to the midline was reflected, the brain was retracted laterally in the parietal region, the posterior two-thirds of the corpus callosum were transected, and the tumor was thus exposed. Through this approach Dandy was able to remove successfully one of three tumors in the pineal region.

A transventricular approach to the pineal region was used by Van Wagenen (477) in 1931. A similar approach was described by Horrax (234) in 1937: in the first stage a part of the parietal lobe was resected and in the second stage the tumor itself was attacked. In 1939 Bagenstoss and Love (11) suggested a double approach: at the first stage the tumor was partially removed through a transcallosal route; later, extirpation was completed by means of a suboccipital craniotomy.

The operative removal of pineal tumors by any method has been attended by high mortality and in general it was due to the relative inaccessibility of the gland; attempts at extirpation have usually ended unsatisfactorily because most pinealomas invade the adjacent midbrain structures. At the present time the generally accepted treatment is by radiation therapy combined, if necessary, with one of the operations designed to relieve obstructive hydrocephalus.

In 1858 Wallman (491) described a *colloid cyst* within the third ventricle, and in 1910

[11] Dandy apparently was unaware of Ballance's operation in 1908.

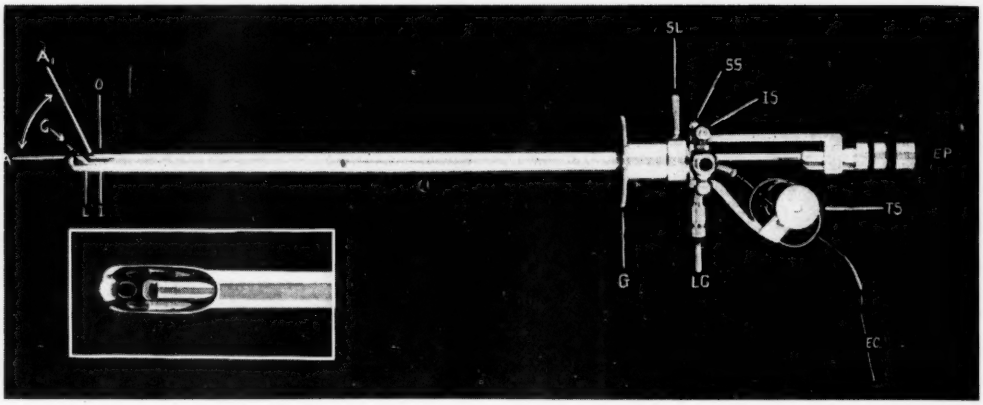


FIG. 27. Ventriculoscope developed by Scarff in 1936 for the endoscopic cauterization of the choroid plexus in the treatment of nonobstructive (communicating) hydrocephalus.

The instrument consists of the following elements: a sheath for introduction of the working parts of the ventriculoscope into the ventricle; a lens system with a lens (*L*), an eye-piece (*EP*), and with a fore-oblique field angle of vision (A-A_1); a movable electrocautery tip (*C*) advanced or withdrawn by a thumb screw (*TS*); two small lights (*L*) at the fore-end of the instrument connected by a light cord (*C*) with a battery box; and an irrigating system receiving Ringer's solution from a reservoir (not shown) through a stopcock (*IS*) and delivered through small tubes to outlets near the operating end of the instrument (*I*).

Sjövall (436) first suggested the relationship of these tumors to the paraphysis. These are small round encapsulated tumors filled with colloid matter. Because they are small and lie in the midline they produce no localizing or even lateralizing neurologic symptoms or signs, but because of their strategic position within the third ventricle they characteristically produce intermittent bouts of obstructive hydrocephalus manifested clinically by headache, nausea, vomiting, and papilledema. While the symptoms and signs just enumerated may arouse suspicion of the presence of colloid cyst of the third ventricle, positive preoperative diagnosis of such a lesion cannot be made clinically and has only been possible since the development of ventriculography by Dandy.

It is, therefore, a matter of some historical justice that Dandy should be the first to diagnose accurately the presence of such a tumor preoperatively and subsequently to expose and remove it. Following is the succinct verbatim report by Dandy (119) in 1922 of the first preoperative diagnosis, localization, and surgical removal of a colloid cyst of the third ventricle:

> In one patient, a woman, 24 years of age, the only symptoms were those referable to intracranial pressure. By cerebral pneumography, it was determined that each lateral ventricle was greatly enlarged, but there was no communication between them. Hence we concluded that there must be a tumor in the third ventricle and occluding each foramen of Monro; that the tumor must be small, because neither ventricle was dislocated away from it. A large bone flap was turned down as in a pineal approach, and the corpus callosum split posteriorly for about 5 to 6 cm. The right lateral ventricle was then opened through the mesial wall at the septum lucidum. No tumor could be seen; the right foramen of Monro seemed normal on inspection from this lateral ventricle, but a probe would not pass through it, an obstruction being encountered in the third ventricle. The foramen of Monro was then widened and a small encapsulated, spherical tumor, about 1 cm. in diameter, easily shelled out *in toto*. The tumor was of ependymal origin. The patient recovered. *Without cerebral pneumography localization of the tumor and consequently its removal would have been impossible.*

It was nearly 8 years before Dandy saw a second colloid cyst of the third ventricle, and even in 1933, in his monograph on "Benign Tumors in the Third Ventricle of the Brain" (132), Dandy was able to report only 5 such tumors.

Hydrocephalus—Advances in Treatment, 1934 to 1955

Although a sound rationale for the treatment of nonobstructive hydrocephalus by extirpation of the choroid plexus from the lateral ventricles had been proposed by Dandy (113) in 1918, the operation which he devised to accomplish this

end was technically a very poor one and resulted in the immediate postoperative death of 3 of the 4 children on whom he attempted it. The basic defect of his operation lay in the fact that in order to excise the plexuses "surgically" he had to empty the ventricle of the cerebrospinal fluid; this allowed the thinned-out walls of the ventricles (cerebral cortex) to collapse, which in turn resulted in profound shock to the patient. The course of events is graphically told in Dandy's own words:

> . . . Following escape of the fluid, the thin brain walls collapse. . . . The mechanical kinking of the larger vascular trunks by angulation of the infolding brain must have a pronounced effect on circulation. . . . In 3 (of 4) cases of this series . . . there was an immediate operative collapse beginning with pallor of the face and body, rapid feeble pulse which quickly became imperceptible, cold clammy perspiration, rapid shallow and irregular respiration. . . . These things invariably began with evacuation of ventricular fluid . . . *death will follow almost immediately on the release of the fluid.*

Although Dandy reported in his original article that he operated upon 4 patients by this method, only one patient survived. No subsequent cases in which this treatment was given were ever reported by him.

Endoscopic cauterization of the choroid plexuses was tentatively tried by Dandy in 1922, but rejected. However, the value of this technique was clearly demonstrated in 1934 by Putnam (386), and a few months later by Scarff (406). The ventriculoscopes (FIG. 27) developed by these two workers differed considerably in their construction, but the surgical principle behind their use was the same, namely, destruction of the choroid plexuses without allowing the escape of the cerebrospinal fluid from the ventricles. This prevented collapse of the thinned-out cortex and enormously decreased operative shock and the consequent mortality (FIG. 28).

In 1943, Putnam (387) reported on 42 children upon whom he had performed endoscopic cauterization of the choroid plexuses between 1934 and 1942. His results may be tabulated as follows:

Hospital deaths	11 (25%)
Later deaths	15 (33%)
Survivors	16 (42%)

Of the 16 survivors, 1 was reported in good physical and mental health nine years after operation; 2, six years after operation; and 1, three years after operation.

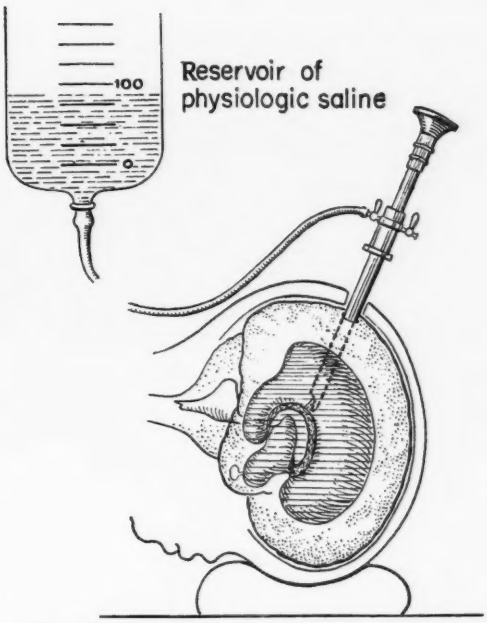


FIG. 28. The principle of endoscopic cauterization of the choroid plexuses embodied in Scarff's ventriculoscope. A constant head of pressure is maintained within the ventricles throughout the cauterization, thus preventing collapse of the thinned-out cortex and eliminating the shock which accompanied Dandy's original open operation.

In 1942 Scarff (409) had published a second paper on this subject reporting endoscopic cauterization of the choroid plexus for relief of nonobstructive hydrocephalus in 20 infants; a summary of his results is given in the following tabulation:

Hospital deaths	3 (15%)
Poor results (discharged from hospital but without permanent relief of intracranial pressure)	7 (35%)
Good results (discharged from hospital with permanent reduction of intracranial pressure to normal levels)	10 (50%)

In 1952 Scarff (416) published a third paper on the subject, giving detailed reports on 19 additional patients operated upon by him since 1946 with the following results:

Hospital deaths	1 (5%)
Poor results	3 (15%)
Good results	15 (80%)

The third paper, published in 1952 (416), contained detailed follow-ups of the 10 children described in the 1942 paper as cured of hydrocephalus: 4 had died of unrelated causes, 3

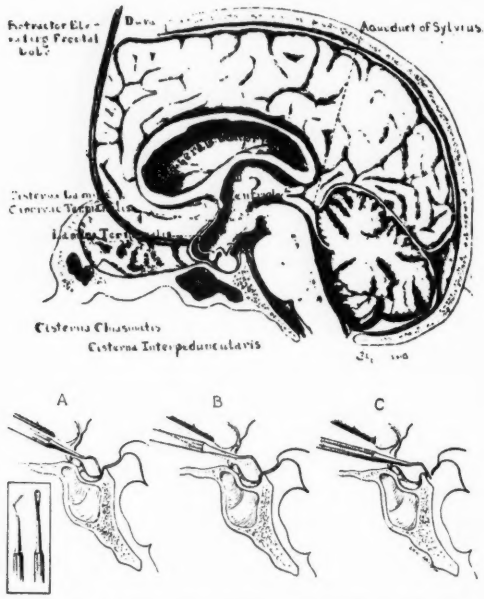


FIG. 29. Puncture of the lamina terminalis and floor of the third ventricle as described by Stookey and Scarff (1936). This is a form of third-ventriculostomy used for the treatment of obstructive (noncommunicating) hydrocephalus. The operation provides for drainage of the cerebrospinal fluid from the obstructed ventricles into the cisterna terminalis and the cisterna interpeduncularis, whence it can be distributed along the sulci out over the cortex and be absorbed by natural processes.

The upper figure illustrates the anatomic and physiologic basis of the operation. The lower figure illustrates the minute technique of the puncture of the floor of the third ventricle.

were physically well but mentally retarded, and 3 were receiving average, or better than average, school marks. Follow-up (a minimum of 3.5 years) of the patients in the second series found 11 (58% of the series) of those "cured" to be of apparent average, or better than average, mentality.

The principle that in the treatment of *obstructive* hydrocephalus it is necessary to drain the cerebrospinal fluid from the obstructed ventricles into a subarachnoid space, whence it can be removed by natural physiologic mechanisms, was first stated by Dandy. In 1922 Dandy (117) described an operation for establishing a communication between the third ventricle and the cisterna interpeduncularis (third ventriculostomy): he approached the chiasm through a small frontal flap, divided the optic nerve, elevated the optic chiasm and tract, and made a puncture into the hypothalamic portion of the third ventricle. He performed this operation on 6 patients but gave no case reports and made no claim for its success. He subsequently modified his technique to avoid dividing the optic nerve; this he did by approaching the hypothalamus through a temporal flap and along the floor of the middle fossa (FIG. 25). There are no case reports of this operation by Dandy.

In 1936 Stookey and Scarff (454) reported a different method of performing third ventriculostomy, which they described as "puncture of the lamina terminalis and floor of the third ventricle." The technique of this operation is shown in the accompanying illustrations (FIG. 29).

Subsequently (1951) Scarff (415) reported the results of puncture of the lamina terminalis and floor of the third ventricle performed by Stookey and himself on 34 patients between the years 1936 and 1950. Case reports were given of all of their patients; the results are summarized as follows:

	Number of cases	*Hospital deaths*	*Poor results*	*Good results*
Aqueduct stenosis...	16	2(13%)	4(25%)	10*(62%)
Tumors.....	13	1(8%)	3(23%)	9 (69%)
Miscellaneous.....	5	2(40%)	3(60%)	—
Total.....	34	5(15%)	10(29%)	19 (56%)

*Patients all living and well (1951); survival periods: 6 weeks, 8 months, 14 months, 2 years, 2.5 years, 3 years, 4 years, 5 years, 15 years.

In 1939 Torkildsen (473, 474) of Oslo reported a new palliative procedure "for use in cases of inoperable occlusion of the Sylvian aqueduct" which consisted of passing a small rubber tube from the occipital horn of one of the lateral ventricles of the brain out through a small occipital trephined opening and thence beneath the scalp and the posterior cervical muscles to the cisterna magna (FIG. 30). Torkildsen reported using this procedure in 4 cases, all with good results. In 1948 Torkildsen (475) reported the use of his procedure in 8 cases of tumor in the pineal region with one postoperative death, and in 11 cases of tumor in or near the third ventricle outside of the pineal region, with 2 fatalities, an operative mortality of 15 per cent. In 1952 Scarff reported the results obtained with Torkildsen's method in 20 collected cases in which operation was done at the New York Neurological Institute during the period between 1941 and 1951, as follows:

Hospital deaths	3 (15%)
Poor results (operative survival without permanent relief of intracranial pressure)	8 (40%)
Good results (survivals with permanent relief of pressure)	9 (45%)

In 1955 Paine and McKissock (352) reported their results with Torkildsen's operation:

Hospital deaths	5 (16%)
Poor results	9 (31%)
Good results	16 (53%)

After the revival of interest in the treatment of hydrocephalus which took place between 1934 and 1939, there followed a 10-year lull in the interest in this subject. However, about 1949, largely because of the development of plastic tubing which is less irritating to tissues than ordinary rubber tubing, there was a fresh revival of interest in the treatment of hydrocephalus directed to the development of operations for draining obstructed cerebrospinal fluid out of the ventricles or subarachnoid spaces into organ systems or body cavities other than the natural cerebrospinal fluid channels. These operations are now generally referred to as "cerebrospinal fluid shunts." These shunting operations undoubtedly received their stimulus from the earlier successful "tubing" procedure described in 1939 by Torkildsen (473).

In 1949 Matson (307) reported what he described as a "new operation" for the treatment of communicating hydrocephalus, *lumbo (arachnoid)-ureteral anastomosis*. His operation was, in fact, merely a revival of an operation which had been described by Heile (227) in 1925 using plastic tubing (252) instead of rubber, and it was successfully carried out by him in 4 patients. It had been used by Christopher (58) in 1929, by Davidoff and Bancroft (140) in 1932, by Lehman (276) in 1934, and by Sachs (401) in 1942. In 1953 Matson (309) reported that he had performed this operation upon 64 children, of whom 45 were living and 42 (65%) presented "satisfactory results to date." About 10 per cent had had to be reoperated upon for occlusion of the arachnoid end of the tube; about the same number had experienced aborted spinal fluid infections, usually controlled by antibiotics but resulting in 3 deaths. Considerable difficulty was encountered in maintaining the electrolyte and fluid balance even after they were discharged to go home, especially during periods of fever and gastrointestinal upset; about 20 per cent of the series had died of the complication. Twenty patients had been followed up 2 years or longer.

FIG. 30. Torkildsen's ventriculocisternostomy (1939). One end of a small rubber or plastic tube is introduced through an occipital trephine opening into the posterior horn of one of the lateral cerebral ventricles. The other end is led extracranially and subcutaneously into the cisterna magna where its open end is fastened. This operation is used to relieve obstructive (noncommunicating) hydrocephalus.

The lumboureteral shunt of Matson was, of course, not applicable to the treatment of hydrocephalus caused by obstruction within the ventricles. To remedy this, Matson (308) devised ventriculoureterostomy in 1951, in which he drained cerebrospinal fluid from an obstructed lateral ventricle into one of the ureters through a long continuous plastic tube leading from the ventricle directly to one of the ureters; he reported that 7 patients were successfully operated upon by him with this method.

In September, 1949 Cone, Lewis, and Jackson (253) presented at the meeting of the American College of Surgeons in Montreal, a small group of hydrocephalic patients who had been treated by peritoneal shunts, the first revival of interest in this particular method of treating hydrocephalus for more than two decades.

As early as 1898 [according to Jackson and Snodgrass] (253) Ferguson drained[12] the spinal fluid from the lumbar area into the peritoneal cavity; but the patient died shortly afterwards and the surgeon was of the opinion that the fatality was due to the sudden loss of fluid. Perhaps the first recorded case of a ventriculo-peritoneal shunt was performed by Kausch[13]

[12]Cited by Davidoff (140).
[13]Cited by Haynes (225).

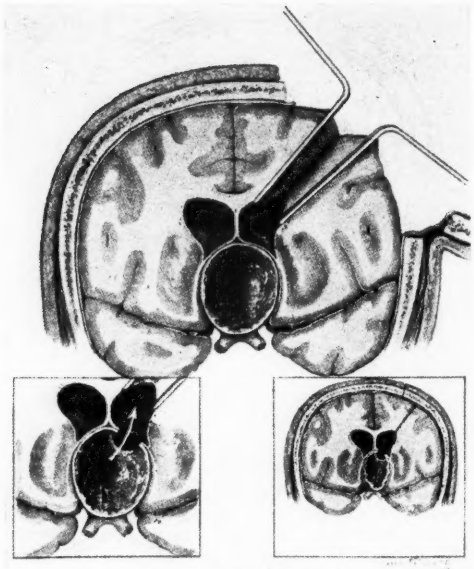


FIG. 31. Intraventricular drainage of craniobuccal cysts (Scarff, 1941).

Center. The frontal horn of the dilated lateral ventricle is entered through a small transcortical incision in the posterior part of the middle frontal convolution. The floor of the ventricle is seen to be pushed upward by the dome of the cyst.

Lower left corner. An opening is made by blunt dissection through the floor of the ventricle and dome of the underlying cyst. In typical cases this opening is anterior to the foramen of Monro and close to the midline, passing through the thin, flat subcallosal gyrus and completely sparing the head of the caudate nucleus.

Lower right corner. After evacuation of the cyst, its wall collapses. This relieves the pressure which the cyst, when distended, exerts against the optic chiasm, the foramina of Monro, and the third ventricle. After the operation the cyst continues to drain into the ventricle.

in 1905 (95). His patient's demise took place 17 hours later. Cushing (1926) reported some success in 12 patients by allowing the excess fluid from the lumbar theca to escape and be absorbed in the retroperitoneal space. However, he discarded the procedure because several patients died of intussusception. There were sporadic reports in the literature regarding peritoneal shunts until World War I, but in the following two decades such operations were virtually abandoned. A review of this subject was published by one of us (I.J.J.) in 1951. The peritoneal shunt was revived by Cone in 1948. Since then his experience with this procedure has been extensive, though unpublished.

In 1952 Ransohoff and Hiatt (392) described a modification of the ventriculoperitoneal shunt for the treatment of hydrocephalus in which they placed the peritoneal end of their tube between the liver and the diaphragm, on the theory that here the tube would be less likely to become closed by the omentum. They reported 6 cases, with good results in all; the longest follow-up was less than 12 months. In 1955 Jackson and Snodgrass (253) reported the cases of 62 patients upon whom they had performed a variety of assorted peritoneal shunts. In only 24 had the shunt functioned for more than one year, and the longest duration of a single shunt was 4 years, in only one patient. Altogether 116 operations had to be performed on the 62 patients. The authors believed that only 39 per cent of their patients were benefited over a long period of time by the procedure.

In the same year (1955) Scott, Wycis, Murtagh, and Reyes (423) reported that in a series of 32 infants with progressive hydrocephalus 67 operations had to be performed; the case mortality was 38 per cent, the survival rate was 73 per cent in the cases of communicating hydrocephalus (lumboperitoneal shunts), and only 40 per cent in the noncommunicating type (ventriculoperitoneal shunts). They reported, "ventriculoperitoneal and lumbar peritoneal shunts have controlled the hydrocephalus in a small percentage (9 per cent) of our cases over a maximum follow-up period of 4 years." The principal difficulty would appear to be failure of the shunt to remain open; methods to prevent this complication are currently being studied.

In 1950 Nosik (342) proposed a ventriculomastoid shunt, employing a cannula to connect the dilated temporal horn of the lateral ventricle with the antrum of the mastoid. Because of the frequency of middle ear infection in childhood, this procedure, theoretically at least, carries with it a significant potential risk of meningitis, and the tube has a tendency to become obstructed. Nosik has been his own severest critic, but it seems probable that the danger of meningitis has been overrated, and with the new antibiotics available it is very slight. This method is now undergoing a favorable re-evaluation.

In 1954 Harsh (222) described an original operation in which he drained the cerebrospinal fluid from the lumbar theca into the peritoneal cavity through one of the fallopian tubes, in other words, a lumbar salpingoperitoneal shunt. He reported using this method in 12 patients; there were 2 deaths and 5 of the patients required 2 or more operative procedures because

of plugging or kinking of the tube for mechanical reasons or as a result of arachnoiditis or peritoneal adhesions about the fimbria; however, 7 patients with salpingothecal shunts and 3 with ventricular salpingoperitoneal shunts were all doing well at the time Harsh's report was published.

In 1954 Ransohoff (391) described for the first time in the literature a ventriculopleural shunt, although in 1952 he had mentioned that he was working on such an operation; he reported good results in 6 patients upon whom he had performed this operation.

Craniopharyngioma—Intraventricular Drainage

The conventional treatment of the cystic craniopharyngiomas (suprasellar, or Rathke's pouch, cysts) has been to drain them through a small opening made in their wall, in the region of the optic chiasm. However, experience has shown that this opening rapidly closes and the cyst soon refills, usually within a 3 month period.

Attempts to prevent refilling of the cyst by destroying its lining at the time of the initial evacuation by means of some sclerosing or fixative fluid (such as Zenker's fluid) have never proved successful. Attempts at radical excision are attended by grave operative risks, and complete extirpation is usually precluded by the fact that the craniopharyngiomas characteristically invade the adjacent hypothalamus to some extent.

In 1941 Scarff (408) suggested dealing with the large *single* suprasellar cysts by establishing surgically an opening between the dome of the cyst and the attenuated floor of the frontal horn of the lateral ventricles (FIG. 31). The cystic cavity would then be irrigated by the cerebrospinal fluid; the slowly formed secretion elaborated by the lining membrane of the cyst would be diluted by the relatively rapidly forming and circulating cerebrospinal fluid and washed away to such "dumping grounds" as the lumbosacral subarachnoid sac.

The case reports of 7 patients treated in this manner were published; in all instances the cyst had first been drained in the conventional manner with rapid refilling and return of the symptoms; in 6 of the patients reoperated upon by cystoventriculostomy long-term freedom from the symptoms followed. Since 1941, 3 more patients with similar conditions have been successfully treated by this method.

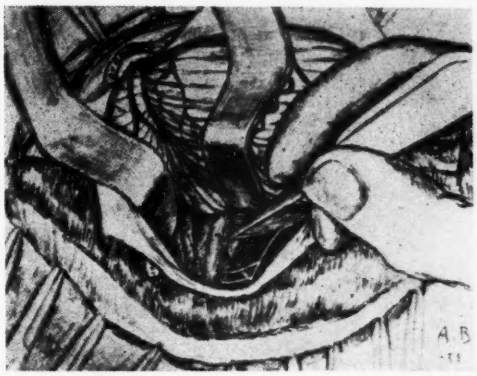


FIG. 32. Sjöqvist's trigeminal tractotomy for relief of tic douloureux (1937).

The method is applicable only to large *single* cysts.

Trigeminal Neuralgia—Advances In Treatment, 1937–1955

In 1937 Sjöqvist (434) described trigeminal tractotomy for the relief of tic douloureux (FIG. 32). Through a suboccipital exploration he exposed the pons near the inferior limits of the fourth ventricle just inferior to the olivary eminence and here made an incision 3 or 4 mm. long into the brain stem at right angles to the medulla to a depth of 3 to 3.5 millimeters. Sjöqvist reported this operation in 10 cases. The results (435) were not entirely satisfactory; the incidence of unpleasant neurologic side effects was high, and after trial by numerous surgeons the method is now rarely used.

In 1952 Taarnhøj (467) of Copenhagen startled the neurosurgical world by reporting the relief of typical trigeminal pain in 10 patients by simply first exposing the ganglion and dorsal root and then enlarging slightly, with a knife, the opening in the tentorium through which the root passes from the posterior to the middle fossa, just over the root. In 1954 he published a full supplementary report (468), giving his experiences with his so-called "decompression of the trigeminal root" in 76 patients of whom 43 were suffering from typical, and 27 from atypical, trigeminal neuralgia. All of these patients experienced complete relief from their trigeminal pain without any accompanying loss of sensation in the face; 7 of the patients subsequently had a recurrence of pain and 5 of them were re-

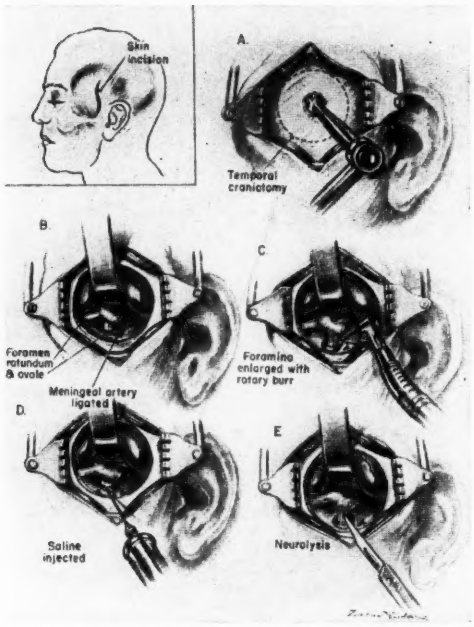


FIG. 33. Treatment of trigeminal neuralgia by "foraminal decompression," described in 1952 by Shelden, Pudenz, *et al.* The foramina rotunda and ovale are simply enlarged with a dental drill; no nerves are divided. These authors reported "gratifying relief" following operation in all 10 consecutive cases.

operated upon with relief. Love (282) and Svien (284) (1954) corroborated Taarnhøj's claims by reporting their own personal experiences with Taarnhøj's operation, slightly modified; of 100 patients, 58 had permanent relief, 31 had recurrence of pain, and in 11 the results were indefinite.

On October 1, 1952, Shelden, Pudenz, Freshwater, and Crue (426) read a paper before the American Academy of Neurological Surgery, in New York City, describing an entirely new type of operation for the relief of trigeminal neuralgia, which they referred to as "foraminal decompression." This operation consisted of "decompression" of the second and third divisions of the trigeminus distal to the gasserian ganglion by exposing the foramina ovale and rotundum intracranially, and then enlarging them with the aid of a motor-driven, high speed dental drill; neurolysis of the peripheral branches with saline solution was then performed, followed by multiple linear incisions in the sheath of the nerve (FIG. 33). In their original presentation the authors reported complete relief of trigeminal pain in all 10 patients upon whom they had operated up to that time, without significant objective impairment of facial sensation. In spite of the gratifying postoperative course of these patients the authors withheld publication of the method and results until a longer period of postoperative observations could be obtained. In 1955, however, they did report the late results of this type of "foraminal decompression" (427); they submitted no statistics and no new data, but stated that "in reviewing our results 3 years after [the introduction of] foraminal decompression, we were impressed with the high percentage of lasting results."

In July, 1954 Stender (455) of Berlin reported the abolition of pain of trigeminal neuralgia in 18 consecutive cases, of which 16 were typical, through the simple expedient of excising the dura overlying the gasserian ganglion (FIG. 34). No nerve fibers were cut. There was no sensory deficit. Stender suggests the name "gangliolysis" for his operation. The longest follow-up period at the time of publication had been 13 months.

In October, 1954 Shelden, Pudenz, Freshwater, and Crue (427) submitted to the editors of the *Journal of Neurosurgery* a description of an operation for the relief of trigeminal neuralgia through the simple exposure of the gasserian ganglion and trigeminal root followed by gentle compression of these structures by a small

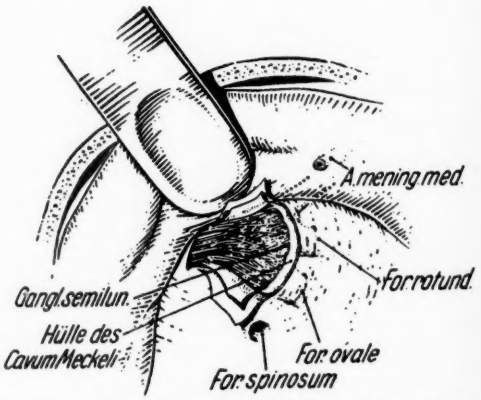


FIG. 34. Treatment of trigeminal neuralgia by simply opening the dura overlying the gasserian ganglion was described in 1945 by Stender. No nerve fibers were cut. The operation was named "gangliolysis." Stender reported 18 consecutive cases with relief of pain.

pledget of cotton held in their forceps or with the back of a blunt dissector (FIG. 35). No nerve fibers were cut. The operation had been carried out on 29 patients, all of whom were completely relieved of their preoperative pain and none of whom had any postoperative facial anesthesia. As will be seen, this operation resembles closely that reported by Stender under the name "gangliolysis," differing only in the minor detail that the American authors, in addition to uncovering the ganglion and posterior root, applied gentle pressure against these structures. Shelden and his associates were apparently unaware of Stender's operation although it appeared in the *Journal of Neurosurgery* 3 months before Shelden and his collaborators submitted their paper.

A new phase in understanding of the mechanisms responsible for trigeminal neuralgia and in methods of treatment is undoubtedly at hand; it holds rich promise of eliminating from the surgery of trigeminal neuralgia the several undesirable features inherent in the old established method of dorsal root section.

Brain Abscesses

The methods utilized for the treatment of brain abscesses have been almost as numerous as the neurosurgeons who operated. For practical purposes all of these methods may be grouped into four general categories:

1. Simple needle aspiration without drainage, as advocated by Dandy (122, 129) who reported that in many cases a single aspiration was adequate to cure small, deeply placed abscesses.

2. Opening and drainage of the abscess through a small catheter, as advocated in 1930 by Coleman (59, 60), by Grant (213), and by McKenzie (301).

3. "Marsupialization," by which is meant removal of cortex overlying the abscess, wide excision of the roof of the abscess, and packing of the abscess cavity widely open with soft gauze which can gradually be removed, the idea being to prevent the formation of secondary pockets (FIG. 36); this method was first used by Cushing (235), later revised and popularized by King (264, 265), and subsequently used and strongly advocated by Horrax (235).

4. Total excision of the abscess or infected brain tissue, initially performed by Vincent (479) in 1934 (FIG. 37-b), and subsequently advocated by Northfield (341), Groff and Grant (216), Pennybacker (371), and LeBeau (275).

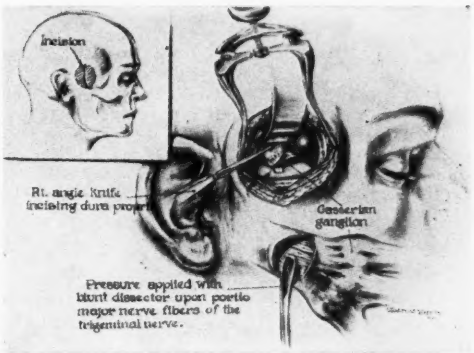
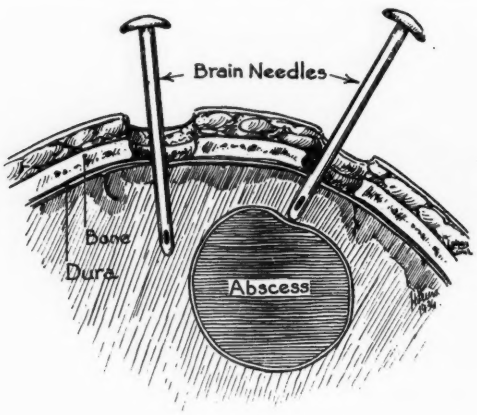

Incision
Rt. angle knife incising dura proper
Gasserian ganglion
Pressure applied with blunt dissector upon portio major nerve fibers of the trigeminal nerve.

FIG. 35. Treatment of trigeminal neuralgia by simple *compression* of the dorsal root, as reported in 1945 by Shelden, Pudenz, *et al*, with complete relief in 29 consecutive cases.

"Above and beyond" any of these methods is the unique procedure described by Kahn (256). His technique was premised on the theory that a deeply located abscess in the presence of increased intracranial pressure would tend to migrate toward a decompressive opening. Having once located the abscess with a cannula (without puncturing the capsule), he enlarged the bony aperture, opened the dura mater widely, and sealed the wound edges with cautery and medicated gauze. The second stage was carried out in 3 or 4 days. If the abscess were smooth-walled and not held to a contiguous focus, it would seek the surface and could be dealt with either by total excision or by one of the conventional methods of drainage. By introducing contrast media in one such case, Kahn was able to demonstrate roentgenographically the dramatic migration of the abscess directly into the cranial defect which he had prepared for it.

In 1938 Horrax (235) wrote a comprehensive review of all the methods employed in the treatment of brain abscess; he called attention to Macewen's fabulous record (298) of 20 patients with brain abscess operated upon by him with a case mortality of only 5 per cent! Horrax stated that no one since Macewen had equaled his record. He summarized the status of the treatment of brain abscesses in 1938 in the following words:

> Irrespective of the surgical methods employed, however, it must be admitted that the *present mortality reports* for brain abscesses are discouragingly high, ranging from 22% up to 56%.



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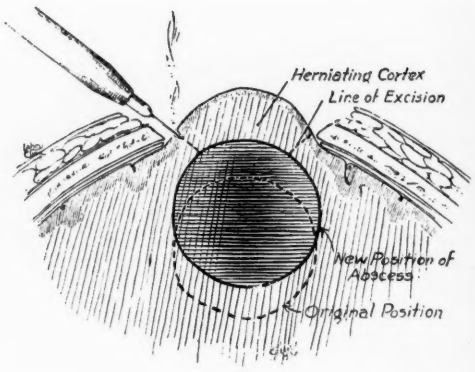

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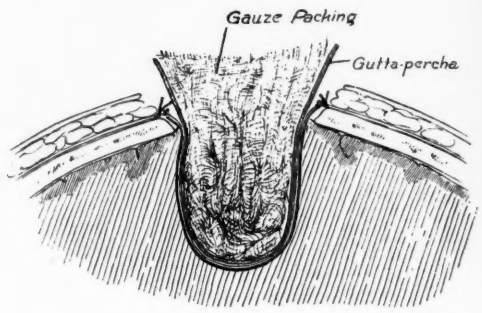


c

FIG. 36. Treatment of brain abscess by marsupialization. This method was occasionally used by Cushing, according to Horrax; later revived and developed by King (1924); subsequently used by Horrax (1938). The technique is designed to prevent the folding of the abscess walls with formation of secondary cysts; the gauze packing is gradually removed as the abscess cavity fills in by granulation from the bottom.

The figures a, b, and c were taken from an article written by Horrax in 1938 and demonstrate his technique.

The development of the sulfonamides and antibiotics with their increasingly wide bactericidal spectrum has resulted in a greatly decreased mortality during recent years regardless of the method employed by the individual operator, and it seems probable that the mortality rates for this long-dreaded condition will eventually become even lower than those for tumors of the brain.

Intracranial Vascular Anomalies

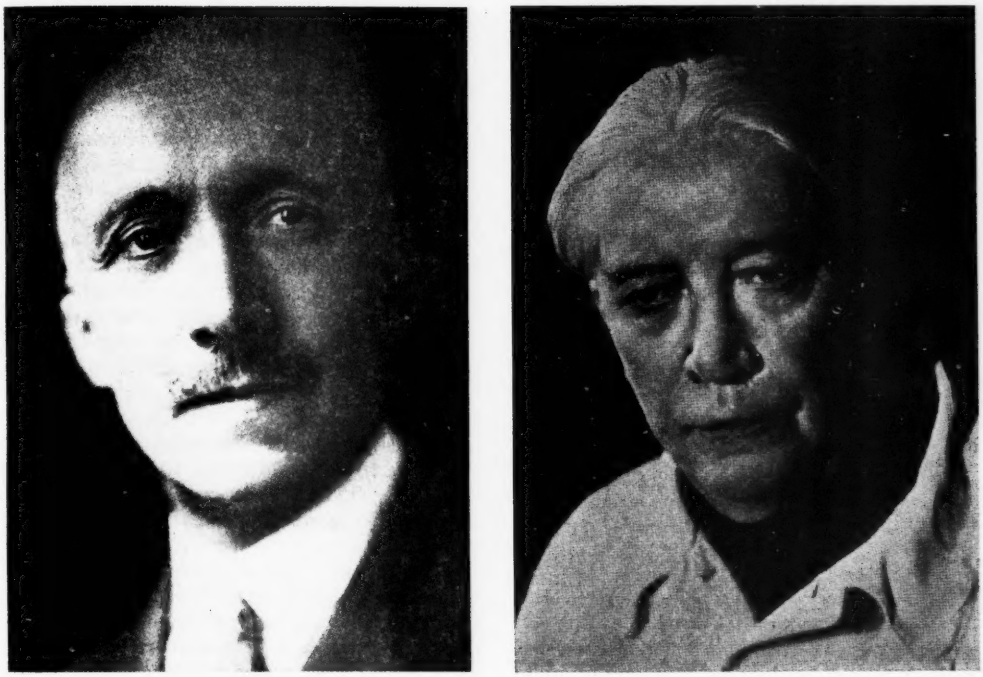
One of the "last frontiers" of neurological surgery, or at least one frontier on which there is currently much activity, is the diagnosis and treatment of intracranial vascular anomalies and tumors.

An indication of the rapidity and extent of expansion in this area of neurosurgery is gained by a brief review of a few historical landmarks recorded in the literature. In 1928 Cushing (106) published a monograph on tumors of the brain arising from blood vessels in which he was able to report only 16 cases which had come under his personal observation; he had attacked none of these surgically. In fact, Cushing declared that "to extirpate one of these aneurysmal angiomas in its active state would be unthinkable."

In the same year Dandy (125) described 8 arteriovenous aneurysms of the brain which had come under his personal observation together with 22 additional cases which he had assembled from the literature. In discussing the treatment of these aneurysms, Dandy stated: "The radical attempt at cure is attended by such supreme difficulties and is so exceedingly dangerous as to be contraindicated except in certain selected cases."

The subsequent development of the surgical attack upon these forbidding lesions may be attributed primarily to Olivecrona's early insistence that they should be dealt with directly, and his own early, courageous efforts along that line. In 1932 Olivecrona (28) successfully removed the first arteriovenous aneurysm from the posterior fossa, and in a monograph published in 1936 (28) he reported 4 additional successful excisions of arteriovenous aneurysms.

Dandy was not far behind. In March, 1937 (135) he exposed a small saccular aneurysm



a b

FIG. 37. Two great French neurosurgeons. a, Thierry de Martel; b, Clovis Vincent.

arising from the right internal carotid artery close to the origin of the posterior communicating artery, and placed a silver clip across the neck of the aneurysm. In his discussion of this case he stated that "the present effort is but a beginning, or a suggestion that an aneurysm at the circle of Willis is not entirely hopeless." In 1944 Dandy (137) published a classic monograph entitled "Intracranial Arterial Aneurysms," in which he reported that between 1937 and 1944 he had operated directly upon 36 intracranial aneurysms, with 9 operative deaths (25 per cent), 20 cures (55.5 per cent), and 1 additional probable cure. If the number of aneurysms in which direct surgical attack on the lesion was undertaken (30) is used for a statistical basis, then 70 per cent of Dandy's patients were cured by surgery.

In 1948 Olivecrona and Riives (349) published a comprehensive review of the subject together with the report of a total of 43 aneurysms directly attacked with only 4 fatalities, an over-all operative mortality of only 9.3 per cent.

By 1948 Olivecrona had thus clearly established the feasibility of direct surgical attack upon intracranial aneurysms, and thereafter we begin to find reports coming in from other neurosurgeons of successful experiences with these lesions. In January, 1951 Poppen (381) reported 143 surgically treated cases of intracranial aneurysms. Among this number, 101 patients were subjected to ligation of the carotid artery in the neck with 3 deaths (3%), 18 were subjected to "trapping" of the aneurysm between silver clips intracranially with 1 death (5%), 14 were subjected to intracranial excision of the aneurysm with 2 operative deaths (15%), and 3 were subjected to exposure of the aneurysm but without direct attack, with 1 death (33%). Also, in January, 1951 Bassett (22) reported the removal of 18 intracranial aneurysms with only 2 deaths (11%). In August, 1951 Falconer (154) reported on 50 consecutive patients with leaking intracranial aneurysms treated surgically by either carotid ligation, intracranial exposure, or a combination of both procedures with 9 deaths

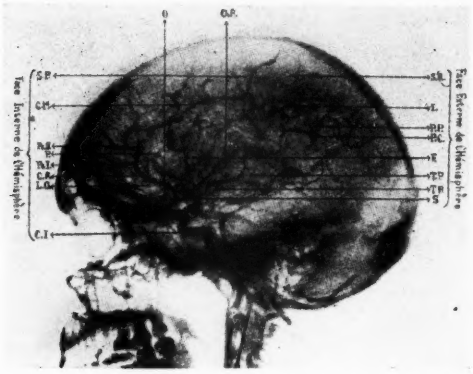


FIG. 38. Neurosurgery is indebted to Moniz for the introduction of cerebral angiography (1927). The current great and growing attack on intracranial vascular anomalies was unquestionably initiated by Moniz' introduction of this immensely valuable diagnostic technique. The above roentgenogram, which appeared in a report by Moniz in 1927, was one of the earliest published arteriograms.

(18%); 33 of his patients made good recoveries, 5 patients, although disabled, were leading economically useful lives, and 3 patients were severely disabled. Falconer contrasted these favorable figures with those he had observed after conservative treatment, namely, a mortality rate of 50 to 60 per cent, with an additional 20 to 25 per cent of permanent disabilities.

In 1953 Norlen and Olivecrona (340) compared the results of three different methods of treating intracranial aneurysms of the circle of Willis. They reported that (1) of a series of 523 patients with spontaneous hemorrhage from intracranial aneurysms who received no surgical treatment 66 per cent died of the first or a subsequent hemorrhage, (2) of 17 patients with bleeding intracranial aneurysms who survived the first hemorrhage and were subsequently treated by ligation of the carotid artery in the neck, 20 per cent died as a result of the procedure and an additional 25 per cent were seriously and permanently incapacitated, and (3) among 63 patients with bleeding aneurysms who were treated by direct attack upon the aneurysm, there were only 2 deaths (3%). Later in the same year, Norlen and Barnum (339) reported direct surgical attack upon 24 aneurysms of the anterior communicating artery only with 2 operative deaths and 2 subsequent deaths, a mortality rate of 16 per cent for this especially difficult group of aneurysms. In 1953 Steelman *et al.* (453), after an excellent review of the current literature, reported on the surgical treatment of 56 intracranial saccular aneurysms with an over-all operative mortality of 4.7 per cent.

Another side of the picture, i.e., "conservative surgery," was presented in 1953 by Black and German (31). They reported on 35 patients with intracranial aneurysms of the internal carotid artery, all treated by simple ligation of the internal carotid artery with 2 operative deaths (5.7% operative mortality); 2 patients died of intracranial hemorrhage after leaving the hospital (a case mortality of 11.5%); 3 died of other unrelated causes; 19 patients (54%) were living and well at the time the report was made.

Many others, whose work our present space precludes mentioning, have contributed to this rapidly growing field. Many issues remain unresolved, but the present concentration of effort in this field augurs well for their ultimate wise solution.

The introduction of cerebral arteriography (FIG. 38) by Moniz (325, 326) in 1927 unquestionably provided the immediate stimulus to release the fresh and aggressive attack which is now opening up the field of surgery of intracranial aneurysms and blood vessel anomalies. Neurosurgery owes Moniz an immeasurable debt of gratitude.

Stereotaxic Techniques

Stereotaxic techniques (FIG. 39) for studying the physiology of the brain and for treating certain conditions were first applied to the human being in 1947 by Spiegel and Wycis (438, 439). They have been employed for studying the electrophysiology of structures deep within the brain and for making discrete lesions for a variety of therapeutic purposes, such as the treatment of psychoses, the relief of pain, and the abolition of dyskinesias. The literature is too extensive to review here.

Spinal Cord Tumors

Once the problem of infection had been overcome by the strict application of antiseptic and aseptic techniques, surgery of the spine offered no major technical difficulties.

A number of years passed, however, before the technique for laminectomy finally became standardized as we know it today. During those formative years the earliest operators frequently

used a chisel and mallet to cut through the lamina. Fearing that the concussions produced by this method would injure the cord, others developed bone-cutting forceps, shears, or punches for biting through the lamina. Cushing was prone to use a round burr on a Hudson drill to perforate the lamina and then finish the removal by means of bone-cutting forceps. There was a period when much attention was paid to the development of osteoplastic laminectomies in which the spinous processes and laminae of several vertebra, sometimes still attached to the paravertebral muscles and sometimes without muscular attachments, were removed and replaced after the intraspinal surgery had been completed.

Gradually, however, a trend toward simplification of the technique for laminectomy gained favor and by 1910 or 1915 most neurological surgeons were using a midline incision of the soft parts and employing simple bone-cutting rongeurs to remove piecemeal the spinous processes and laminae, as laminectomy is generally performed today. It is noteworthy that Chipault (56), as early as 1894, strongly advocated and used a simple technique for laminectomy, which is essentially the same as that generally used today.

Hemilaminectomy was first conceived and used by an Italian, Bonomo (32), between 1890 and 1900, and subsequently by Abbe (2) of New York, by Alessandri (8, 9) in 1905 and 1906, and by Taylor (471) of New York in 1910. In 1928 Stookey (458) described a modification of Taylor's original laminectomy and strongly advocated the use of hemilaminectomy even in the removal of cervical cord tumors.

Once the vertebral canal had been unroofed the techniques employed for the removal of spinal cord tumors were simply adaptations of operative techniques concurrently being worked out for the removal of intracranial tumors and do not here need any repetition or amplification.

Horsley (212) in 1886[14] was the first to remove a spinal cord tumor successfully; it was a small, intradural, *extramedullary*, encapsulated tumor, which was probably a meningioma (FIG. 4).

The first removal of an *intramedullary* neoplasm was successfully performed in 1907 by von Eiselsberg (147). In 1927 Cushing (198) completely removed from an 11 year old girl an extensive intramedullary tumor which extended from the medulla to the midthoracic region. The patient not only survived but her condition showed remarkable improvement. The most extensive intramedullary neoplasm which has been removed with success was an encapsulated ependymoma extending from the junction of the medulla and the cervical cord to the tip of the conus medullaris, which was removed in two stages by Horrax (238) in 1936, the patient surviving and experiencing a marked degree of functional recovery.

The surgical treatment of syringomyelia was first undertaken by Abbe (4), of New York, who in 1891 emptied a cyst by aspiration with temporary improvement. From that time on various techniques and modifications were proposed for the treatment of this condition, but the results in general were disappointing in that the cysts tended to refill. In 1949 Kirgis and Echols (266) devised a method whereby a shallow loop of wire, attached to the dura, is allowed to project

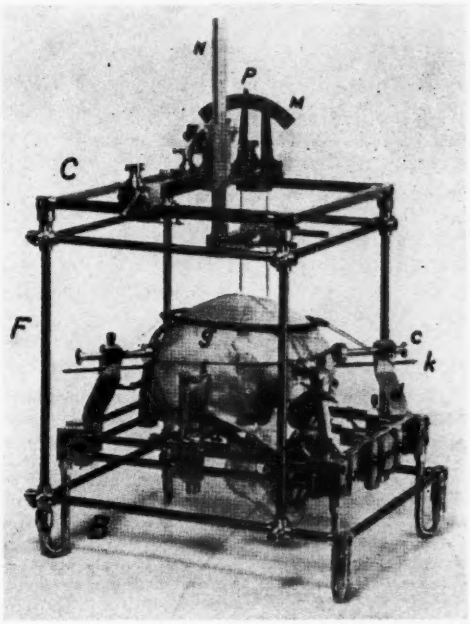
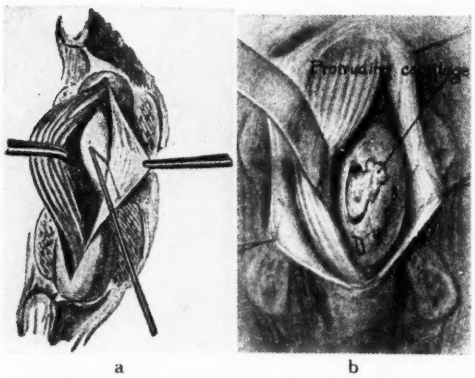


FIG. 39. A modern stereoencephalotome (Wycis). Stereoencephalotomy has been carried out for the relief of mental disorders, intractable pain, petit mal, and extrapyramidal disorders.

[14]The "tumors" which Macewen reportedly removed before Horsley's tumor were not in fact neoplasms at all but *extradural* masses, organized hematoma or granulation tissue, secondary to spinal trauma or infection (tuberculosis), as careful reading of Macewen's original reports clearly reveals.



a b

FIG. 40. The earliest recorded cases of ruptured intervertebral discs.

a, Krause's case (1908). Drawing made at operation of a traumatically extruded midlumbar disc causing flaccid paraplegia. This hard piece of fibrocartilage was removed successfully by Krause with full recovery of the patient. Krause apparently did not recognize the true nature of the fibrocartilaginous mass which he removed, thinking it a "chondroma."

b, Dandy's case (1925). Drawing made at operation of a spontaneously extruded nucleus pulposus in the midlumbar region causing flaccid paraplegia, and successfully removed at operation with full recovery of function. Dandy had a second, almost identical, case a few months later and then quickly recognized the true traumatic nature of the lesion.

The similarity between Krause's case and Dandy's first case is striking.

into the syringomyelic cavity through a dorsal midline incision in the cord; the slight constant movement of this loop, accompanying all body activity, tends to keep the incision into the myelic cavity open. These workers report excellent long-term results.

Undoubtedly one of the most important developments of spinal surgery since 1920 has had to do with delineation of the pathology, the clinical features, and the surgical treatment of herniations of the intervertebral discs. Virchow (480) in 1857, Kocher (268) in 1896, and Walton (494) in 1905 reported cases of extrusion of the nucleus pulposus seen by them at the autopsy table. In 1911 Middleton and Teacher (322) described 2 cases of ruptured intervertebral disc observed at autopsy, in patients who before death had suffered low back ache and sciatic pain.

In 1911 Goldthwaite (209) of Boston published a fascinating paper after intimate study in the dissecting room of many lumbosacral articulations. Through deductive reasoning, he postulated the traumatic extrusion of a nucleus pulposus to be responsible for the paraparesis of acute onset in a patient then under his own care. He even went so far as to draw a sketch of the hypothetical herniated nucleus pulposus. He also persuaded Cushing to explore the lumbar spine, but Cushing failed to find the hypothecated lesion. Notwithstanding this disappointing setback, Goldthwaite persisted in his views that such a herniated nucleus pulposus could produce the symptoms of low back pain and sciatica, and published a long, profusely illustrated article in an attempt to persuade surgeons to look for these herniations. Unfortunately his brilliant hypothesis was too far in advance of its time to attract the attention which it deserved.

The first successful removal of a ruptured intervertebral disc was undoubtedly carried out by Fedor Krause in 1908. This case was first reported by Oppenheim and Krause (350) in the *Deutsche medizinische Wochenschrift* in 1909, and later described in detail in Krause's "Surgery of the Brain" (273) in 1911. The neurologic symptoms and signs were carefully evaluated for Krause preoperatively by Oppenheim, who concluded his detailed consultation note with the following sprightly recommendation: "Internal medication proving of no avail, I am for laminectomy, first at the level of the 3rd lumbar vertebra." At operation performed on December 23, 1908, Krause found a large mass of cartilaginous tissue within the vertebral canal compressing the roots of the cauda equina (FIG. 40a); this he successfully removed with great improvement in the patient's neurologic status thereafter. The pathologists described the specimen as consisting "mainly of cartilage tissue with few cartilage cells; the fibrous elements were fairly strong and blood vessels extremely few; in only a few places aggregations of granulation-cells were present; no necrosis, few calcified plaques, no bone tissue." This mass was diagnosed as an "enchondroma," but the fact that the patient first experienced pain and weakness in his legs soon after he had attempted to prevent the fall of a man by catching him with both arms, being powerfully "jack-knifed" in so doing, makes it seem almost certain that the cartilaginous mass removed by Krause was not a neoplasm but a traumatic extrusion of a nucleus pulposus. Furthermore, the patient made an excellent recovery following its removal.

It seems incredible that more than 20 years passed after Krause's removal of an extruded nucleus pulposus before the next herniated nucleus pulposus was encountered and removed, but such is the fact. In 1929 Dandy (128) operated in a case almost identical with that of Krause's (FIG. 40b) in which a large spontaneously extruded nucleus pulposus had compressed the cauda equina sufficiently to produce marked paraparetic symptoms. Within a few months Dandy operated in another case almost identical with his first. Dandy was quick to recognize the significance of this and states in his report of these cases:

> The fact that the two cases appeared only a few months apart leads me to believe that the lesion may not be so infrequent, although a review of the literature has failed to disclose other cases of their kind. The lesion is a completely detached fragment of cartilage from an intervertebral (lumbar) disk. . . . It bulges dorsally into the spinal canal as a tumor, and by compression the roots of the cauda equina cause motor and sensory paralysis, loss of reflexes and of rectal and vesical control. [However] . . . the lesion is undoubtedly of traumatic origin.

In France, Petit-Dutaillis and Alajouanine (6,7,373), as early as 1928, had published papers on the importance of protruded discs in relationship to cauda equina symptoms.

In 1934 Mixter and Barr (324) published an important paper describing a series of 19 ruptured intervertebral discs found by them at operation, and correlated the anatomical findings with the patients' clinical symptoms of low backache and sciatic pain. Their paper clarified the clinical condition so long known as "lumbago and sciatica" and focused attention upon the ruptured intervertebral disc. Since that time a voluminous literature has developed on this subject. From a technical standpoint the operation for the removal of the herniated nucleus pulposus has become progressively simplified, the full laminectomy and transdural approach giving way to hemilaminectomy, then partial hemilaminectomy with extradural removal of the herniated nucleus pulposus was done as described by Semmes, and, finally, the herniated nucleus pulposus was removed through an interlaminar space without removal of any bone as reported in 1939 by Love (281).

In 1928 Stookey (458,460) reported a series of cervical laminectomies during which he had found individual cervical nerve roots displaced dorsalward and compressed by cartilaginous masses originating in the intervertebral discs. He removed these, with relief of the symptoms and signs of root compression. His operative reports were correlated with detailed descriptions of the neurologic findings in each case. The pathologists who examined the tissues called them "chondromas"—they would undoubtedly be recognized today as typical *herniations of cervical discs.*

Since then Spurling and Scoville (447), Semmes (425), and others (151,152) have written papers on cervical "discs." Love and Keefer (283), more recently, have reported findings of ruptured discs in the thoracic region.

A great boon to spinal surgery has been the development of liquid media opaque to x-rays, which could be introduced through a spinal needle into the spinal subarachnoid spaces. While "myelography" has been a valuable aid in the diagnosis of all types of spinal lesions, it has been especially valuable in establishing or confirming the presence and the exact site of small herniations of the nucleus pulposus. These media all have in common the fact that they consist of some form of iodine in a vehicle suitable for injection into the spinal subarachnoid space. The first of these opaque media was developed by Sicard and Forestier (432) in 1921 and used by them for diagnostic studies in the human being. The substance used by these men became known as "lipiodol." Unfortunately, lipiodol had a high viscosity, was difficult to remove from the spinal canal, was highly irritating, and frequently caused severe adhesive arachnoiditis. It may be of some interest to note, however, that the exact level of the ruptured intervertebral discs removed by Dandy (128) in 1929 was established in each instance by the use of lipiodol.

In 1938 Pool (375) devised an ingenious "myeloscope" by means of which it became possible to view directly the elements of the cauda equina. This promised to obviate the use of lipiodol. Its field of usefulness, however, became rather restricted with the advent of "pantopaque."

In 1944 this opaque medium, pantopaque, which was very much superior to lipiodol, was developed through the joint efforts of the University of Rochester Medical and Dental Schools and the Eastman Kodak Company (454). It has the advantage of having a high surface tension without high viscosity; hence it is easily removed after completion of the examination. It is non-

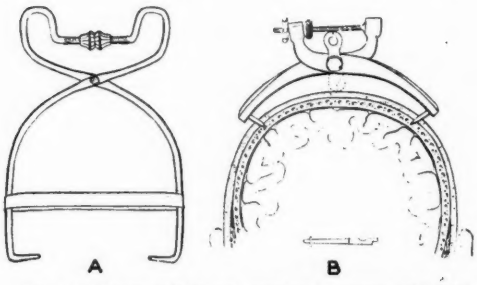


FIG. 41. The use of skeletal traction by means of "skull tongs" has greatly facilitated the treatment of fracture dislocation of the cervical spine and has been responsible for a considerable lowering of mortality and morbidity resulting from this serious spinal injury.

The above drawings illustrate Crutchfield's earliest model (1933) and his present perfected model (1938).

irritating, and little harm results if some of it cannot be removed from the neural canal and must be left there. Pantopaque has been rapidly accepted and is now widely used; it has proved to be an especially valuable aid in the diagnosis and localization of ruptured intervertebral discs.

A very important advance in the treatment of fracture-dislocations of the cervical spine came about through the introduction in 1933 of skeletal head traction by means of "skull tongs" (FIG. 41). The best tongs are undoubtedly those of Crutchfield (66,67,68). These can be quickly applied to the skull of a patient lying in bed, with only 2 cubic centimeters of novocain in the scalp; they accomplish and maintain realignment of the cervical vertebrae; they do away with the older plaster casts encasing the head, neck, and chest, which interfered considerably with respiratory movement and tended to induce pneumonia; they permit the patient to be turned from side to side and from the supine to the prone position. The use of this technique—skeletal traction—has certainly resulted in a definite reduction of posttraumatic mortality following severe spinal injury.

A new technique for care of the bladder in paraplegic patients, known as tidal drainage, was developed by Munro and Hahn (336) and has proved to be one of the greatest possible boons in the care and rehabilitation of patients suffering from this distressing condition. By this simple technique it is possible not only to keep the bladder free from infection indefinitely but at the same time to maintain a normal bladder capacity against the day when voluntary control of the sphincter will return or an automatic bladder can be established. The importance of these two considerations not only in the immediate posttraumatic period but during the rehabilitation of the patient, socially and economically, is immeasurable.

Another extremely valuable technical development in the treatment of the paraplegic patient has been the development of the Stryker frame, by which the paralyzed patient may be easily turned from the supine to the prone position to take pressure off of his sacrum and other bony prominences. The use of this frame has greatly minimized the occurrence of pressure sores in the paralyzed patient. When these have developed it has become general practice to promptly cover the open sore with a full-thickness pedicled graft as soon as the area is clean enough to make this surgically feasible.

The use of Crutchfield tongs, the Stryker frame, tidal drainage, and the prompt covering of pressure areas with full-thickness pedicled grafts has brought about a very much better life expectancy for the paraplegic than was possible 20 years ago.

Surgery of the Peripheral Nerves

Since 1905 there has been a great increase in our knowledge regarding the regeneration of injured peripheral nerves and the methods for treating them. These advances in knowledge have come in successive increments following the two great World Wars when the incidence of peripheral nerve injuries was, for brief periods, tremendously increased. The number and range of contributions to the pathology and treatment of injured nerves during the past 50 years are too voluminous to permit any detailed recounting of them in this writing. However, most of the knowledge has been reviewed and presented in three excellent books by Stookey (457) (1922), Pollock and Davis (383) (1933), and Haymaker and Woodhall (224) (1945).

B. THE PATHOLOGIC PHASE

DELINEATION OF PATHOLOGICOCLINICAL SYNDROMES

The second phase in the evolution of neurosurgery as we know it today has to do with the classification of tumors and their correlation with clinical symptom complexes, that is, the *establishment of pathologicoclinical syndromes*. This phase of development was one to which Cushing dedi-

cated himself with great and sustained vigor, and the delineations of the pathologicoclinical syndromes which will be briefly described are in large measure the result of his efforts.

This work was begun about 1911 or 1912 with the publication by Cushing (87) of his monograph on "The Pituitary Body and Its Disorders"; it ended with his description in 1932 of the basophilic adenoma and its correlation with the clinical syndrome which bears his name (103,104).

As time passed and more and more tumors of the brain were seen and operated upon, it gradually became evident that intracranial tumors could be divided into two great categories.

In the first category are those tumors, comprising about half, which take origin from the surface of the brain, its appendages, or its coverings. They arise from fixed sites of election, present constant and characteristic clinical syndromes, and in general offer the most favorable prognoses.

The second category of brain tumors is comprised of those which arise from within the substance of the brain itself, through malignant changes in the character of the brain cells, and these are generally referred to as "gliomas." Although the intramedullary tumors or gliomas do not produce fixed clinical syndromes as do the extramedullary tumors, they follow certain patterns of behavior and give rise to fairly constant clinical pictures which can be recognized and serve as guides to treatment and permit the formulation of reasonable prognoses.

An effort will be made to review briefly the various pathologicoclinical syndromes presented by both the extramedullary and the intramedullary tumors.

INTRACRANIAL TUMORS—EXTRAMEDULLARY GROUP

Tumors Arising from the Periphery of the Brain, Its Appendages, or Its Coverings

The pituitary adenoma. The pituitary tumors were the first to receive special study (87) and undoubtedly are the intracranial tumors best known to the general medical profession.

All of the pituitary tumors are known to arise from the anterior lobe, that portion formed from an upward evagination of the buccal mucosa into the cranial cavity during embryonic life. This lobe is composed, normally, of some cells which contain granules easily stained with dyes and, hence, known as chromophilic cells; it also contains other cells, which do not possess these granules receptive to dyes, known as chromophobe cells. The granules in the chromophilic cells are thought to represent drops of secretions elaborated by the cells which have been fixed in the staining process; the chromophilic cells therefore are believed to have active endocrine functions. Because no such granules are found in the chromophobe cells, they are considered to have no endocrine function. Some of the chromophilic cells have a special affinity for acid (eosinophilic) stains, hence are known as acidophilic (eosinophilic) cells; other of the chromophilic cells have an affinity for the basophilic dyes and hence are known as basophilic cells.

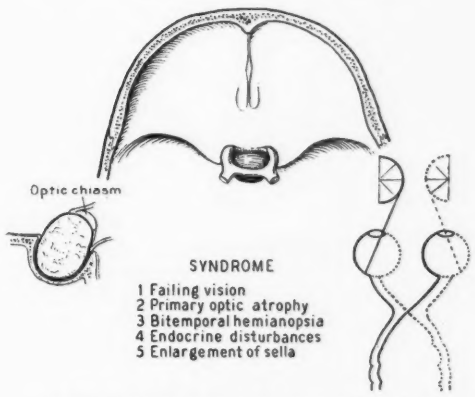


FIG. 42. Pituitary adenoma (chromophobe type).

Pathologic hyperactivity of the chromophobe cells produces active endocrine disturbances; hyperactivity of the acidophilic (eosinophilic) cells produces, among other things, an excess of skeletal growth—gigantism where the process begins in early life, and acromegaly (82, 87), where the hyperactivity begins in later life; hyperactivity of the basophilic cells produces vascular hypertension, osteoporosis, hirsutism, diabetes mellitus, excessive adiposity, especially around the neck and thorax—a clinical complex known as Cushing's syndrome (103, 104). This is probably brought about indirectly through hyperstimulation, by the basophilic cells, of the adrenal cortex.

Overactivity of the chromophilic cells is accompanied by "hyperplastic" changes, which have seemed to justify the terms eosinophilic and basophilic "adenomas." However, the pathological and clinical manifestations of these two "tumors" are confined almost entirely to the endocrine disturbances already mentioned and rarely result in true tumefaction of the gland; hence they are seldom, if ever, today the subject of surgical interference (98).

Overactivity of the chromophobe cells, on the other hand, is unaccompanied by active endocrine disturbance, manifests itself almost entirely by cellular proliferation, and gives rise to the chromophobe pituitary adenoma.

The first and certainly the best known of the classic syndromes of intracranial tumor is that

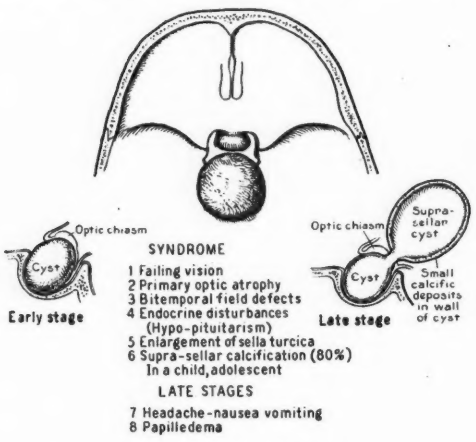


Fig. 43. Craniopharyngioma.

produced by the chromophobe pituitary adenoma. It is the one surgical tumor of the pituitary body (87, 89) (FIG. 42).

This tumor characteristically occurs in young adults, that is, in persons between 20 and 40 years of age. The chromophobe adenoma produces its pathologic and clinical effects solely by direct pressure upon adjacent nervous and bony structures. One of the first things which this tumor does is to compress and destroy the chromophilic cells within the pituitary body which are responsible for the normal endocrine activity of the gland. One of the earliest clinical evidences of tumor, therefore, is the loss of sexual function, which in the male is indicated by the loss of libido and potentia and in the female by premature cessation of the menses.

As the tumor increases in size it enlarges the sella turcica, which can be clearly seen in x-ray films. As it grows upward, it compresses the optic nerves and the optic chiasm. Pressure on the optic nerves results in progressive failure of vision in both eyes and eventually in primary optic atrophy. Compression of the optic chiasm interrupts the optic nerve fibers which arise from the medial half of each retina and cross over through the optic chiasm to join the optic tract on the opposite side of the brain. As a result, the temporal field of vision in each eye is impaired, producing the characteristic bitemporal hemianopsia.

We thus have produced the classic syndrome of the chromophobe adenoma, namely, (1) bilateral impairment of vision, (2) bitemporal hemianopsia, (3) bilateral optic atrophy, (4) loss of sexual function, and (5) enlargement of the sella turcica.

This tumor should be suspected whenever there is a progressive loss of vision in both eyes which cannot be corrected by glasses; the visual fields should be tested and roentgenograms of the skull taken, which will promptly establish the diagnosis.

The craniopharyngioma (96, 408) (FIG. 43) is the pituitary tumor of adolescence, occurring characteristically between the tenth and twentieth years of life. It arises from the cells of Rathke's pouch, a remnant of the buccal mucosa which was evaginated upward during embryonal life to form the anterior lobe of the pituitary body. This tumor is also known as the craniobuccal tumor, or Rathke's pouch tumor.

In the early stages of its growth the craniopharyngioma lies entirely within the sella turcica and produces pathologic and clinical effects almost identical to those produced by the chromophobe pituitary adenoma, namely, (1) bilateral impairment of vision, (2) bitemporal hemianopsia, (3) bilateral optic atrophy, (4) enlargement of the sella turcica, and (5) suppression of sexual development and function.

As the tumor enlarges, however, it breaks out of the sella and comes to lie in great part above the sella. This suprasellar portion is often cystic, whence the synonym "suprasellar cyst." This part of the tumor grows very slowly, so that there is often time for fine deposits of calcium to be laid down within it. This distinctive "supra-

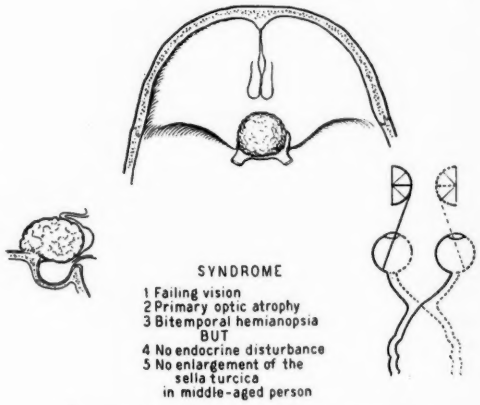


FIG. 44. Meningioma of tuberculum sellae.

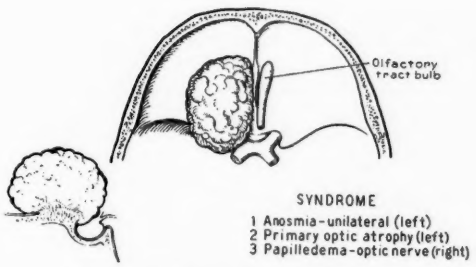


FIG. 45. Olfactory groove meningioma.

sellar calcification" can be seen in x-ray films in about 80 per cent of the cases.

Eventually, as the suprasellar portion of the tumor continues to enlarge, typical symptoms and signs of generalized intracranial tension appear, including headache, nausea, vomiting, and stupor.

The craniopharyngioma should be suspected whenever an older child or an adolescent suffers bilateral impairment of vision which cannot be corrected by glasses. Roentgenograms of the skull will reveal enlargement of the sella, and in 80 per cent of the cases the telltale calcification above the sella.

The meningioma of the tuberculum sellae (99, 109), or suprasellar meningioma (FIG. 44), is a firm, encapsulated fibroblastic tumor which arises from the dura covering the anterior lip of the sella turcica. It grows upward and backward, compressing and stretching the optic nerves and chiasm without, however, invading them. The pressure against these structures produces bilateral visual impairment, bitemporal hemianopsia, and primary optic atrophy in both eyes.

These symptoms and signs thus far closely resemble those produced by the common pituitary adenoma, but here the resemblance ceases. Because the meningioma of the tuberculum sellae grows above the sella and not within it, this tumor does *not* cause enlargement of the sella or suppression of sexual function. Also, the tuberculum sellae meningioma characteristically occurs in persons over 40 years of age, hence in an older group than the pituitary adenoma.

The syndrome of the tuberculum sellae meningioma may be summarized as follows: (1) failing vision, bilateral; (2) bitemporal hemianopsia; (3) primary optic atrophy, bilateral; but (4) without disturbance of sexual function; (5) without enlargement of the sellae turcica.

The key to the diagnosis of this tumor is the bitemporal hemianopsia. Every patient with failing vision and primary optic atrophy should have his visual fields tested. It may be accepted as axiomatic for all practical clinical purposes that only a tumor compressing the chiasm will produce bitemporal hemianopsia.

The olfactory groove meningioma (97, 109, 263) (FIG. 45) is a fibroblastic tumor which arises from the dura along its attachment to the olfactory groove and cribiform plate to one side of the midline of the floor of the frontal fossa.

This meningioma early compresses and destroys the olfactory bulb and nerve on the involved side thus producing a unilateral anosmia which is invariably complete. As the tumor grows backward along the olfactory groove, it eventually overrides the posterior edge of the frontal fossa and compresses the optic nerve as that nerve enters the optic foramen. This results in a progressive loss of vision in this eye and an early optic atrophy of the compressed nerve. Eventually, as the tumor enlarges it causes a general elevation of intracranial pressure and papilledema of the optic nerve of the opposite eye.

The syndrome of the olfactory groove meningioma, therefore, consists of (1) primary optic atrophy in one eye, (2) unilateral anosmia (complete) on the same side, and (3) papilledema in the opposite eye.

The retro-orbital meningioma. The greater wing of the sphenoid bone forms not only the anterior wall of the middle cranial fossa but at the same time the posterior wall of the orbital fossa. The retro-orbital meningioma (50, 93, 94, 109) (FIG. 46), or meningioma of the sphenoid wing, arises

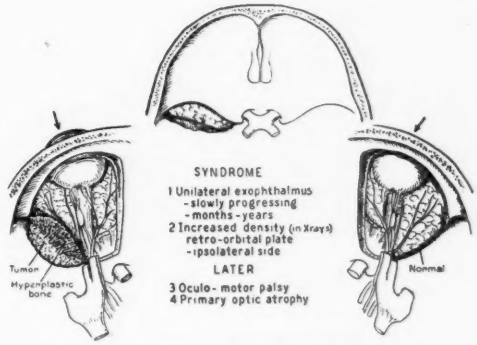


FIG. 46. Retro-orbital meningioma.

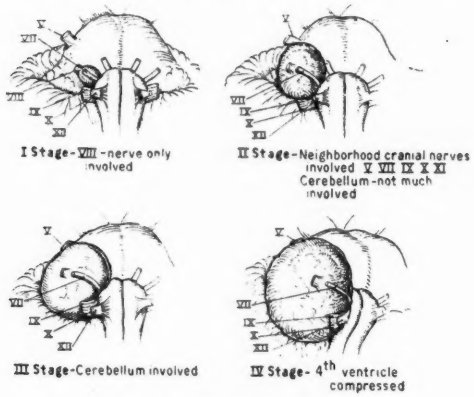

I Stage-VIII-nerve only involved
II Stage-Neighborhood cranial nerves involved V VIII IX X XI Cerebellum-not much involved
III Stage-Cerebellum involved
IV Stage- 4th ventricle compressed

FIG. 47. Acoustic neurinoma.

by a broad base from the dura covering the posterior intracranial surface of that bony structure. Although sometimes globoid in shape and reaching considerable size, this tumor is characteristically rather flat, often not exceeding a half inch in thickness, which has caused the French to call it "meningiome en plaque."

This tumor does not invade the brain and, because its intracranial growth is seldom great, it rarely produces pathologic or clinical effects by pressure against the tip of the temporal lobe. On the other hand, this tumor does invade the dura to which it is attached and produces a striking effect upon the underlying bone of the sphenoid wing. This it stimulates to excessive growth so that this bony septum, which normally is only 1 to 2 millimeters thick, eventually may become 1 to 2 centimeters thick.

As this septum slowly becomes thicker and thicker, it crowds forward the contents of the orbital fossa, including the eyeball, and produces over a period of years a slowly developing unilateral exophthalmos.

Roentgenograms of the skull taken after exophthalmos is apparent will reveal characteristic thickening of the retro-orbital plate on the side of the proptosis. This finding establishes at once the true diagnosis; for while several conditions may produce a slowly developing unilateral exophthalmos, only the retro-orbital or sphenoid wing meningioma produces a simultaneous thickening of the retro-orbital plate.

The syndrome of the retro-orbital meningioma, therefore, consists of: (1) unilateral exophthalmos, developing very slowly over several years' time, plus (2) hyperplasia of the retro-orbital plate, or sphenoid wing, on the side of the proptosed eye.

The acoustic neurinoma (91, 92, 118, 207) (FIG. 47) arises from the eighth cranial nerve as it passes from the petrous bone to the brain stem in the cerebellopontine angle. This tumor is slow growing, encapsulated, and benign.

In the beginning the acoustic neurinoma affects only the eighth nerve, the auditory portion producing tinnitus and later deafness, and the vestibular portion producing disturbances of equilibrium. Because of the slow growth of this tumor, these eighth nerve manifestations may be the only ones for several years. Eventually, however, the tumor becomes large enough to press upon or stretch the seventh nerve, causing slight weakness of the facial muscles; the fifth nerve, causing pain in the face or sensory disturbances of the cornea and face; and the ninth and tenth nerves, causing difficulty in swallowing and speaking.

As the tumor further enlarges, it compresses the cerebellar lobe, producing ataxia and incoordination in finer muscular movements. Finally, as the tumor becomes very large, it may occlude the fourth ventricle, causing acute obstructive hydrocephalus with all the typical symptoms and signs of generalized intracranial pressure.

An acoustic neurinoma should be suspected whenever a case of complete unilateral deafness is associated with any other cranial nerve symptom or sign, especially pain in the face and an absent corneal reflex. The key to early diagnosis, however, is the caloric test for vestibular function. For all practical clinical purposes it may be accepted as true that absence of vestibular responses to this test establishes the diagnosis of an acoustic neurinoma.

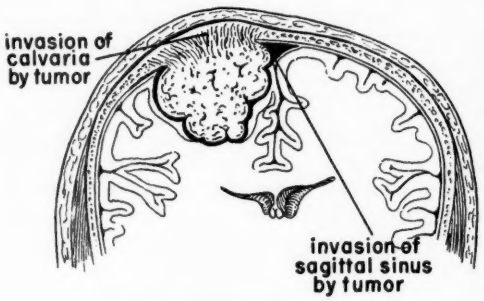


FIG. 48. Parasagittal meningioma.

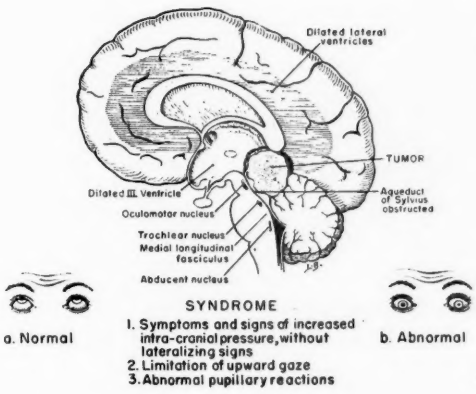


FIG. 49. Pinealoma.

Roentgenograms of the skull taken at this time will show enlargement of the internal acoustic meatus and erosion of the petrous pyramid in approximately 50 per cent of these tumors. Examination of the spinal fluid will early reveal a significantly elevated total protein in practically all cases of acoustic neurinoma.

The parasagittal meningioma (88, 93, 109) (FIG. 48) is a fibroblastic tumor arising from the dura at its junction with the falx near the vertex of the skull and alongside the superior longitudinal, or sagittal, sinus. It grows into the cranial cavity as a globoid-shaped tumor. It never invades the adjacent brain but compresses and displaces it. Its growth is so slow, however, that it may attain a size several inches in diameter before its presence is suspected.

The signs of local pressure, of course, depend upon the exact position of the tumor. If it compresses the frontal lobe, disturbances of personality result; if it compresses the pre-rolandic area, motor paresis of the contralateral upper extremity will follow; if it compresses the post-rolandic cortex, disturbances of sensory function in the contralateral arm will follow; if it compresses the occipital cortex, homonymous hemianopsia will result.

This tumor is also a frequent cause of convulsions, and one of the most common causes of convulsions occurring for the first time in adults. This is true particularly when the tumor arises in the prerolandic or postrolandic area.

In addition to its intracranial growth and resultant pressure effects upon the brain, the tumor grows outward through the dura and invades the overlying bone where it produces a striking and characteristic thickening of the bone. This is a true hyperplasia and in the roentgenogram shows distinctive lines of growth radiating centrifugally from the tumor area. During this period of invasion, vascular channels leading to the tumor increase in number and size, and these can be seen in the scalp on inspection and in the bones of the skull on the x-ray films.

The parasagittal meningioma, therefore, can be recognized by (1) disturbances of cerebral function, either in the form of convulsions, personality changes, or impairment of motor or sensory function, accompanied by (2) local hyperplasia and hypervascularization of the bones of the skull immediately overlying the tumor. These local effects upon both brain and bone may precede entirely any symptoms or signs of generalized intracranial pressure.

The pinealoma (116, 234, 351) (FIG. 49), which is composed of very primitive and undifferentiated tumor cells, gives rise to a unique and remarkable syndrome. Two mechanisms are involved in its production. In the first place, as the tumor grows it presses downward upon the quadrigeminal plate, displacing that structure downward and partially occluding the aqueduct of Sylvius. This produces an obstructive hydrocephalus with all of the characteristic symptoms and signs of increased intracranial pressure.

As the tumor enlarges, this downward pressure is increased and is transmitted to the oculomotor nuclei situated in the floor of the aqueduct and to the superior longitudinal fasciculi.

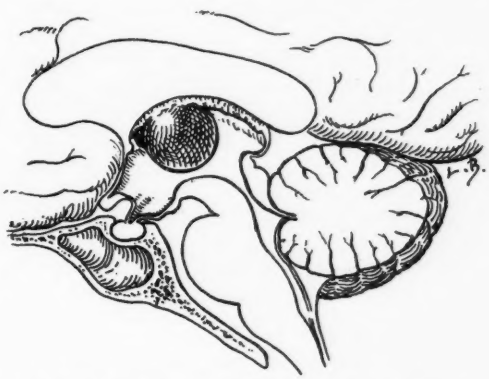


FIG. 50. Colloid cyst of third ventricle. 1. Obstructive hydrocephalus—intermittent. 2. Localizing signs—none.

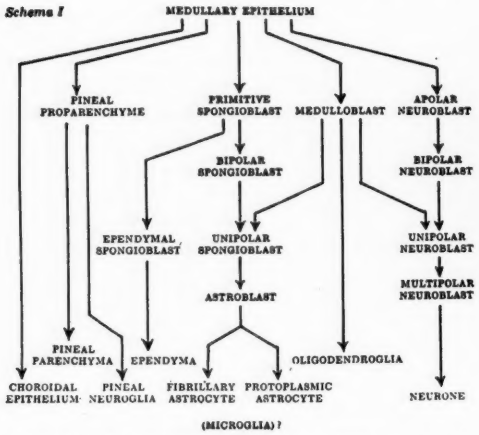


FIG. 51. The "family tree" of the various cellular elements of the brain from which are derived the different types of gliomas. Taken from Bailey and Cushing's book (1926), "A Classification of the Tumors of the Glioma Group on a Histogenetic Basis with a Correlated study of Prognosis" (14).

These fasciculi connect the oculomotor nuclei and control conjugate movement of the eyeballs. Interference with these nuclei and tracts results in many oculomotor disturbances. The pupils may become unequal in size; they may react to accommodation but not to light; there may be inability of the eyeballs to converge despite the absence of any true paralysis of the internal rectus muscles. The most striking disturbance of all, however, is paralysis of upward gaze; the patient is unable to rotate the eyes upward beyond the horizontal plane despite the fact that there is no paralysis of either lateral or downward gaze. This unique clinical sign is produced only by the pinealoma.

The syndrome of the pinealoma consists, therefore, of the following: (1) symptoms and signs of generalized intracranial pressure, and (2) disturbances of conjugate eye movements, in particular paralysis of upward gaze.

The diagnostic point to be emphasized is the testing of upward gaze in all patients with symptoms and signs of generalized intracranial pressure. If this is done regularly, no pinealoma will escape early detection.

The colloid cyst of the third ventricle (119, 129, 132, 382, 436, 491) (FIG. 50) is a small epidermoid approximately 1.5 to 2 centimeters in diameter. It is lined with squamous cell epithelium and filled with thick colloid matter. It enlarges

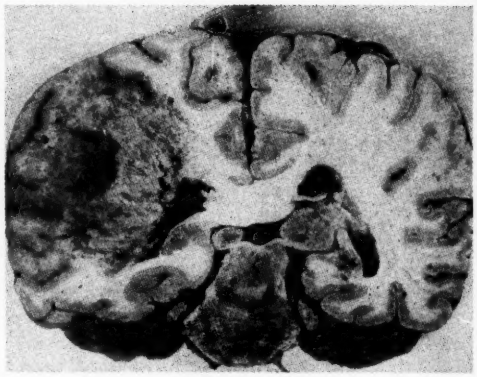


FIG. 52. Coronal section through a glioblastoma multiforme. This glioma is the most primitive and malignant intracranial tumor of adult life. It is found only in the cerebral hemispheres.

slowly, and characteristically does not give symptoms until the second or third decade of life.

This cyst is loosely attached to the anterior part of the roof of the third ventricle. It is thus near the interventricular foramina (foramina of Monro) through which the cerebrospinal fluid escapes from the lateral ventricles into the third ventricle in the course of its normal circulation. When the cyst has reached a certain size it tends to act like a ball valve and to obstruct the two foramina of Monro. At first this obstruction is intermittent and infrequent, but as the cyst enlarges the obstruction becomes more constant and of greater degree. The clinical manifestation of this intermittent obstruction consists of recurrent bouts of severe headache, nausea, and vomiting. As the condition progresses, papilledema of the optic nerve heads develops. Under certain circumstances occlusion of the foramina of Monro may become complete so that stupor, coma, and even death will result. Even in the advanced cases, however, the tumor rarely produces neurologic signs of localizing or lateralizing value.

A colloid cyst of the third ventricle should be suspected when a patient suffers intermittent bouts of generalized headache of great and increasing severity and frequency without any other neurologic signs excepting papilledema. However, the diagnosis can be established only with the aid of ventriculograms, which should be taken whenever this condition is suspected.

The syndromes just described are produced by the relatively benign extramedullary tumors. These are the tumors of which early recognition

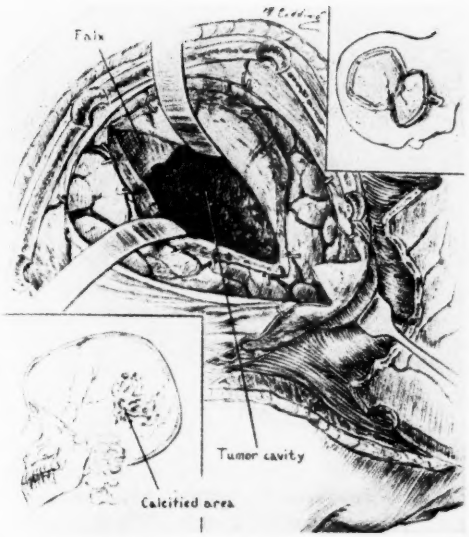


FIG. 53. The oligodendroglioma is the most slowly growing of the gliomas. Its growth allows time for the deposition of small particles of calcium in the tumor which often can be seen in x-ray films of the skull.

is especially rewarding. Fortunately, each of them, with the possible exception of the colloid cyst of the third ventricle, declares its presence by symptoms and signs which are clear and unmistakable to those on the lookout for them. They present a stimulating challenge to the rhinologist, ophthalmologist, otolaryngologist, and general physician, who see the patients first.

INTRACRANIAL TUMORS—INTRAMEDULLARY GROUP

The "family tree" of the embryonic cells giving rise to the different types of gliomas was worked out by Percival Bailey (14) in Cushing's laboratory and published in 1928 in their classic monograph entitled "A Classification of the Tumors of the Glioma Group" (FIG. 51).

As a matter of simple convenience for our present purpose, the intramedullary or infiltrating tumors may be divided into three groups: those arising (a) above the tentorium, (b) below the tentorium, and (c) within the brain stem.

Tumors arising above the tentorium.

The infiltrating tumors above the tentorium occur almost invariably in adults; there are three different tumors in this group:

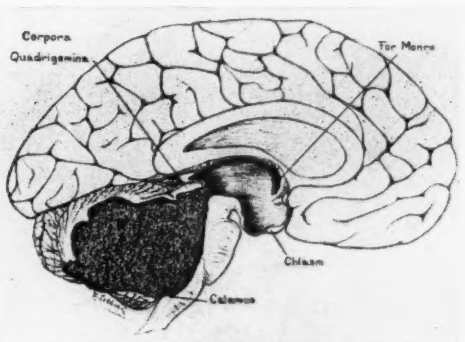


FIG. 54. The cerebellar medulloblastomas arise in the "roof" of the fourth ventricle in very young children. They are the most rapidly growing of all of the cerebellar tumors and the most malignant of all the intracranial tumors of childhood.

The *glioblastoma multiforme* (14, 105) is the most rapidly growing and malignant of all brain tumors found in adults (FIG. 52). It can never be totally eradicated with surgery, and its growth is only very temporarily halted by irradiation.

The *astrocytoma* (14, 105) is more slowly growing and less malignant. While it is rarely possible to totally eradicate this tumor by surgery, it is often very favorably affected by x-ray therapy, and instances of 5, 10, and even 15 years' survival after partial removal are known.

The *oligodendroglioma* (13, 14, 105, 240) is very slowly growing and hence the least malignant of all the intramedullary tumors. Because of its slow growth calcific deposits (FIG. 53), detectable with x-rays, are often present in it. Patients have been symptomatically well for 10 or more years following partial extirpation and x-ray therapy.

Tumors arising below the tentorium.

In the subtentorial group there are four infiltrating tumors. Three of these tumors arise from the "roof" of the fourth ventricle: (1) the *medulloblastoma*, (2) the *astrocytoma*, and (3) the *hemangioblastoma*. The fourth tumor in the subtentorial group, the *ependymoma*, arises from the "floor" of the fourth ventricle.

The three tumors arising from the roof of the fourth ventricle may be characterized for our present purposes as follows:

The *medulloblastoma* (100, 105), microscopically resembling a lymphoma (FIG. 54), occurs only in children, usually in the first decade, and is the most frequent brain tumor of childhood; it is the

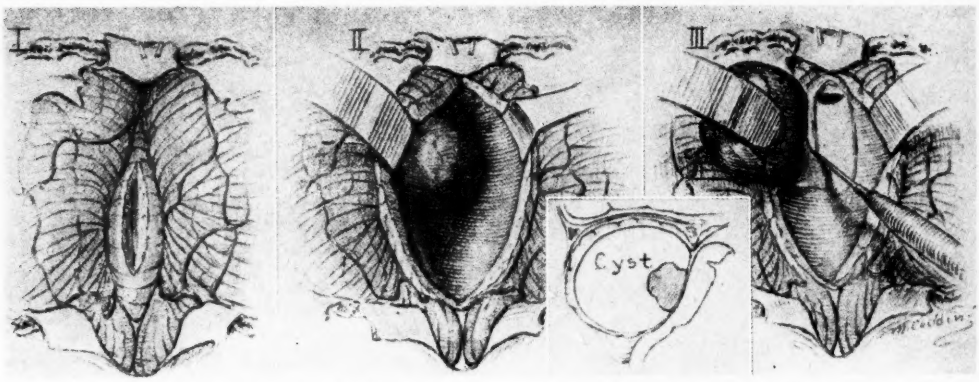


FIG. 55. The cerebellar astrocytomas arise in the "roof" of the fourth ventricle. They occur characteristically in older children and adolescents. They are moderately slow in growth, solid or cystic. The cystic form has a small mural nodule of tumor on the wall of the cyst; excision of the nodule alone will effect a permanent cure.

most rapidly growing and malignant of all the intracranial tumors, frequently seeding into the cerebrospinal fluid and giving rise to transplantations elsewhere within the cranial cavity or in the subarachnoid space.

The *astrocytoma* (101, 105) which occurs characteristically in older children or adolescents, in the second or third decade of life, is frequently cystic with only a small nodule of solid tumor in the wall of the cyst (FIG. 55); if this simple nodule can be cleanly removed, permanent cure is usually accomplished. Experience has shown that astrocytomas may be among the most favorable tumors of the brain. Even the solid tumors often grow very slowly and respond exceptionally well to x-ray therapy. Five and 10 year survivals with good health are known after subtotal removal followed by x-ray therapy.

The *hemangioblastoma* (105, 106, 305, 347, 433) occurs in an older age group, characteristically

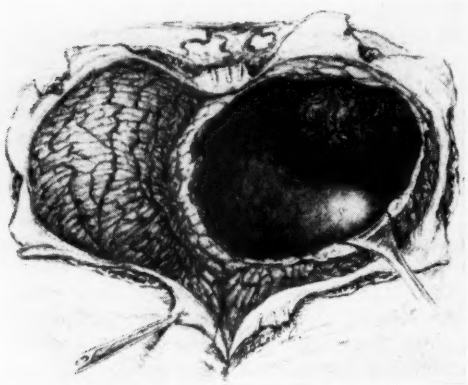


FIG. 56. The hemangioblastomas also arise in the "roof" of the fourth ventricle. They occur in adults. Characteristically they grow slowly and are the least malignant of the posterior fossa gliomas. They may be solid or cystic. In the cystic type excision of the mural nodule will effect a permanent cure. Occasionally the solid tumors are exceedingly vascular, making surgical extirpation difficult or impossible.

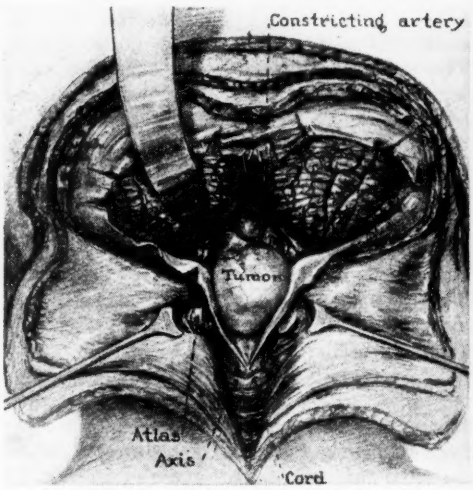


FIG. 57. The ependymomas arise as a rule from the "floor" of the fourth ventricle. They may occur in children, adolescents, or adults. Because of their attachment to the brain stem total surgical extirpation is impossible, but these tumors frequently respond very favorably to x-ray therapy.

in the third or fourth decade of life. It may be either solid or cystic with a mural nodule (FIG. 56). The solid form may be very vascular and difficult to extirpate, but it grows slowly and is often amenable to x-ray therapy; the cystic form can be cured if the mural nodule is removed.

The *ependymoma* (12), arising from the floor of the fourth ventricle (FIG. 57), may occur in any decade of life from the first to the fourth, but most characteristically in the second or third decades. Although the base of the tumor invades the brain stem and cannot be removed, the bulk of the tumor lying within the fourth ventricle usually can be removed. These tumors often respond well to x-ray therapy, and survival of the patient for many years is not uncommon.

Tumors arising in the brain stem.

Tumors of the brain stem are, as a rule, "bipolar spongioblastomas" (15), a special cell-type which is usually slowly growing and is often quite responsive to x-ray therapy. There are two special sites of elcction: (1) the optic chiasm, and (2) the pons.

FIG. 58. Gliomas of the optic chiasm usually occur in children. In a large percentage of cases they invade the hypothalamus. For this reason, complete surgical extirpation of the tumor, even at the total sacrifice of vision, can seldom be achieved. On the other hand, when recognized early, these tumors respond extremely well to x-ray therapy in a high percentage of cases.

FIG. 59. Schematic representation of the clinical syndromes of the extramedullary brain tumors (gliomas).
Supratentorial group:
1. Glioblastoma (adults), very rapid growth.
2. Astrocytoma (adults), slow growth.
3. Oligodendroglioma (adults), very slow growth.

Infratentorial group:
(Roof of fourth ventricle)
1. Medulloblastoma (children), very rapid growth.
2. Astrocytoma (adolescents), mod. rapid growth.
3. Hemangioblastoma (adults), slow growth.

(Floor of fourth ventricle)
4. Ependymoma (children and adults), slow growth.

Brain stem group:
1. Glioma (spongioblastoma unipolare) of optic chiasm and hypothalamus (children, more frequently).
2. Glioma (spongioblastoma unipolare) of pons (adults, more frequently).

The *glioma of the optic chiasm* (306) characteristically occurs in children during the first decade of life. The symptoms and signs are those of a slightly lateralized chiasmal lesion in which one optic nerve is affected more and earlier than the other. The optic foramen on the side of the more affected nerve is usually enlarged. The sella may or may not be enlarged, but frequently undermines the tuberculum to produce a characteristically "J-shaped" appearance as viewed in lateral roentgenograms of the skull. The tumor frequently (possibly always) involves the hypothalamus (FIG. 58). Surgical extirpation can be achieved only by elective sacrifice of vision, and then is usually incomplete because of invasion of the hypothalamus. Fortunately these tumors often respond very well to x-ray therapy; the arrest of growth for many years has been observed.

FIG. 60. Charles A. Elsberg

The *glioma of the pons* (15) is more apt to occur in the middle age group, although not invariably. Its clinical manifestations vary widely. It may produce early extensive disturbances of the cranial nerves and long tracts or, again, it may produce surprisingly few. It may or may not cause early hydrocephalus. Diagnosis can sometimes be established only with the aid of pneumoencephalography. This tumor can never be attacked surgically; individual cases show great variation in their response to x-ray therapy.

Summary of the clinical syndromes of intramedullary tumors. The typical locations, age incidence, and comparative rates of growth of these various infiltrating tumors are shown in the accompanying schema (FIG. 59).

As will be seen from consideration of the preceding pages, if the (1) age of the patient, (2) site of the tumor, and (3) rapidity of the tumor's growth be known, it then becomes possible with reasonable accuracy to tell preoperatively the (cellular) type of the tumor, whether the unremoved portions of the tumor will respond favorably to irradiation therapy, and, what the life expectancy of a given patient will be.

SPINAL CORD TUMORS; RUPTURED INTERVERTEBRAL DISCS

As neurosurgical techniques in general improved and explorations of the vertebral canal were accompanied by smaller and smaller risks, familiarity with the various types of intravertebral tumors and their clinical symptoms and signs increased proportionately.

Thus as early as 1925 we find published a definitive book on "Tumors of the Spinal Cord" by Elsberg (150) (FIG. 60), which has remained more or less authoritative on this subject up to the present time. In his book Elsberg gave detailed case reports of 81 personally verified tumors of the spinal cord. Of these, 42 were extramedullary tumors, mostly endotheliomas (meningiomas); 12 were giant tumors of the conus and roots of the cauda equina (ependymoma of the filum terminali); 14 were extradural tumors of various types; and 13 were intramedullary tumors. Detailed histories, neurological examinations, operative notes with illustrations, photographs of the gross tumors, and photomicrographs of the tumors accompanied each case report. Very little has been added to our knowledge of tumors of the spinal cord since Elsberg's book, except perhaps the use of different words by the pathologists to designate the tumor types.

Pathologically, at the present time, there are recognized intramedullary ependymomas, astrocytomas, and cysts; extramedullary meningiomas (dural endotheliomas) and neurofibromas; and extradural sarcomas (lymphosarcomas).

There are no specific syndromes associated with the different types of spinal cord tumor as there are with the various types of intracranial tumors. However, the symptoms and signs produced by the lesions involving the various spinal segments and roots, and the symptoms and signs produced by lesions affecting the various motor and sensory tracts in the cord, have all been established. The neurologist or neurosurgeon today finds little difficulty in determining, on purely clinical grounds, the segmental level at which a tumor within the vertebral canal is located; not infrequently he is further able to tell with reasonable accuracy whether the tumor is intramedullary or extramedullary.

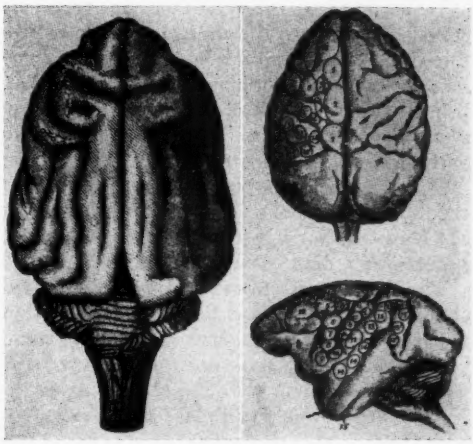


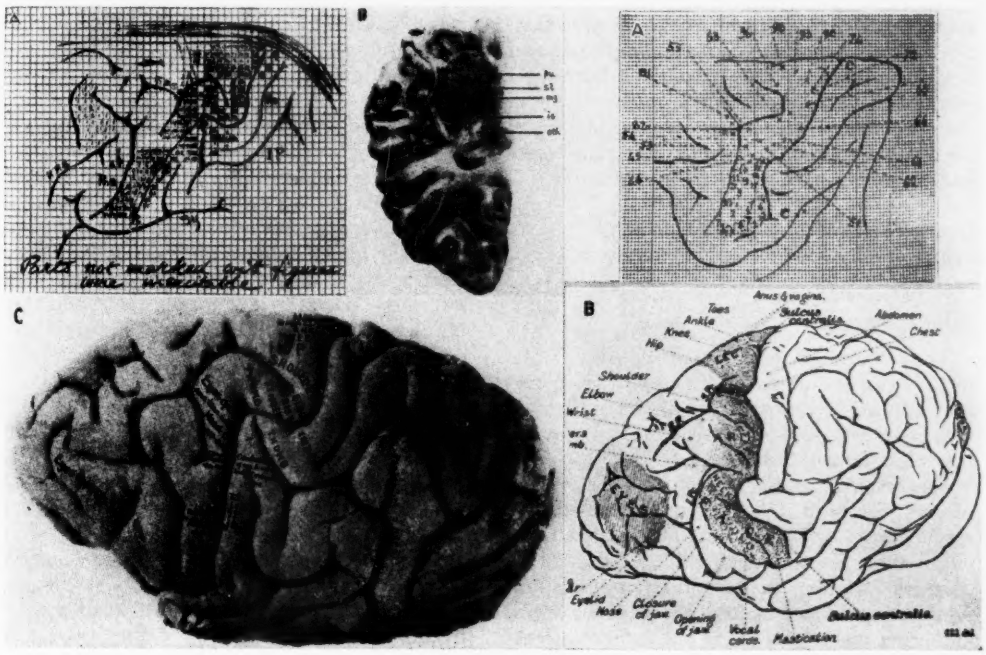
FIG. 61. History-making "maps" of the cerebral representation of motor function in laboratory animals found by the early physiologists as a result of electrical stimulation of the cortex. These provided the immediate and original stimuli by which neurologic surgery were set in motion.

Upper left. Fritsch and Hitzig initiated the new technique for studying the physiology of the brain by electrical stimulation of the brain and demonstrated for the first time, in 1870, that focal motor responses could be elicited from the contralateral extremities by stimulating the cerebral cortex (of dogs). This historic illustration, reproduced from their original article, shows the first identification of "centers," for the neck muscles (††), for the forelimb (#), for the "hindlimb" (00), and for the face (△).

Upper right. Ferrier, in 1873, confirmed the observations of Fritsch and Hitzig and extended them to the brains of a great number of other animals, including the monkey (above). His experiments may be said to have established on a secure basis the localization of function in the cerebrum.

Lower right. Sherrington and his school, from 1901 to 1906, continued Horsley's work and investigated with utmost precision (*A*) the motor cortex of the higher anthropoid apes. The lower chart (*B*) is a map of the motor areas of the chimpanzee's brain as determined by Sherrington and Grünbaum.

Lower left. Beevor and Horsley, from 1887 to 1890, confirmed and extended the work of Ferrier. Introducing exquisite laboratory techniques (*A* and *B*), these investigators "re-examined in minute detail" the motor cortex of the monkey, including the highly developed brain of the orangutan (*C*).



In addition to the syndromes produced by spinal cord tumors, the clinical syndromes produced by *adhesive arachnoiditis* and by *varicès of the cord* and cauda equina have also been established. The syndrome of the former consists of signs of a "level lesion" of the cord associated with a partial manometric block and a normal (or slightly elevated) spinal fluid protein; that of the latter consists of signs of a "level lesion" of the cord associated with an open manometric system and a high spinal fluid protein.

The significance of obstruction to the free exchange of cerebrospinal fluid pressures within the spinal subarachnoid spaces and the original "manometric" test for spinal arachnoid "block" was described in 1916 by Queckenstedt (390). In 1928 Stookey (463) refined the Queckenstedt test to make manometric determinations far more accurate and reliable in the presence of partial spinal "block" and made it possible to establish clinically the presence of not only complete but partial spinal blocks.

Although Krause (273) undoubtedly was the first to operate upon a ruptured intervertebral disc in the lumbar region, it remained for Dandy (128), in 1929, to recognize its true nature. However, the herniations he encountered were massive ones, producing complete paraplegia, and it was not until 1934 that Mixter and Barr (324) established the pathologicoclinical syndrome of the small laterally extruded nucleus pulposus in the lumbar region, giving typical symptoms of low backache and sciatic pain recognized today.

C. THE PHYSIOLOGIC PHASE
APPLICATION OF LABORATORY TECHNIQUES AND CRITIQUES TO THE OPERATING ROOM

Brain Mapping

The demonstration by Fritsch and Hitzig (197) in 1870 (FIG. 61-upper left) that an electric current applied to isolated points on the exposed brain of a dog would produce focal responses in the contralateral extremities was really the "open sesame" to the new field of neurologic surgery; for until it had been established that specific neurological functions had localized representations in the brain, there had existed no basis for assuming that clinical symptoms and signs were produced by focal lesions of the brain, and hence no basis for direct and definitive treatment of such lesions. Three years later (1873) Ferrier (157), who was then working obscurely in the West Riding Lunatic Asylum, mapped out focal "motor points" in a large number of barnyard and laboratory animals (FIG. 61-upper right), and the following year (158, 159, 160) did the same for the brain of a rhesus monkey. In 1887, Horsley (246, 247, 248, 249, 250, 353), with his associates Shäfer and Beevor, beginning where Ferrier had left off, instituted "a further minute research" into the representation of motor function in the brain of the monkey (FIG. 61-lower left). Within a period of 4 years they established the minute representation of motor function in the cortex, the internal capsule, and the spinal cord of the rhesus monkey, and then climaxed their researches with an elaborate investigation of the motor area in the highly organized brain of the orangutan.

From 1902 to 1906 Sherrington and his coworkers (217, 398, 430), taking up the work where Horsley had left off, "mapped out" with painstaking care the cortical representation of motor functions in the chimpanzee and gorilla brains, (FIG. 61-lower right) which closely resemble the human brain in appearance.

It was only natural, as the brains of animals were being mapped out, for physicians and surgeons to want to make "maps" of the brain of man. And so we find Ferrier (162), in 1879, preparing a "map of the human brain" which was based *in toto* upon observations which he had made on the brains of monkeys. In the same year he published an entire volume on "The Localization of Cerebral Disease." In this, he presented figures of a monkey brain and a human brain side by side. On the monkey brain were indicated the motor points which he had identified electrically in 1874; on the human brain were indicated identical motor points. Underneath the figure he wrote this legend: "Upper surface of human brain; the (numbered) circles have the same significance as those on the brain of the monkey."

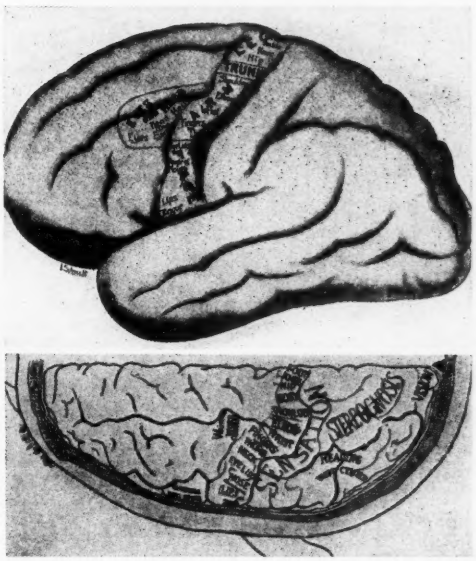
It is important to note that at the time that Ferrier first published this volume there was only one instance on record in which the human cortex had been electrically excited. This was the case described in 1874 by Bartholow (21), Professor of Medicine at Cincinnati, in which he had plunged sharp needle electrodes directly through a defect in the skull of a patient, caused by an eroding epithelioma of the scalp, and thence deeply and blindly on into the underlying brain. By introducing the electrodes in differ-

ent directions Bartholow was able to elicit focal responses in the contralateral arm or leg.[15]

An exact copy of this figure of Ferrier's, showing "motor points on the human brain," appeared without modification in successive editions of "Gray's Textbook of Anatomy" from 1887 to 1901.

Mills and Frazier (322) (1906), Cushing (74, 81, 472) (1907, 1908, 1909), and Krause (273) (1908–1911) all published "maps" of the human cortex (FIG. 62), but it is evident from close reading of the contemporary writings of these men that their own personal experience in stimulating the human brain could not possibly have supplied the data necessary to construct their maps, and it seems evident that they must all have borrowed heavily from Sherrington's map of the gorilla's brain, which so closely resembles that of man, to fill in the huge gaps left by their own limited observations.

[15] In 1893 Dana (110) carried out essentially the same procedure in a patient of his.



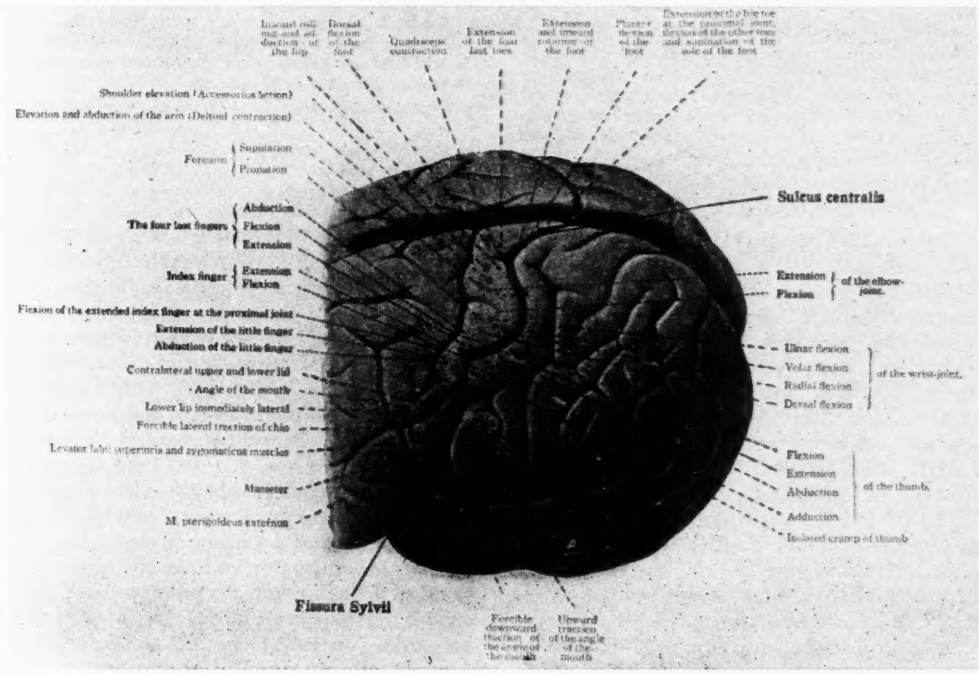
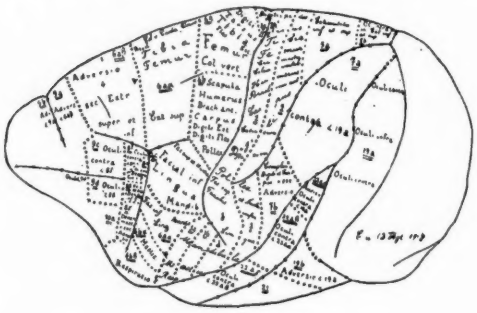


FIG. 62. Early "maps" of the human brain (1905–1910). Stimulated by the work of the physiologists in mapping the brains of laboratory animals, the neurosurgeons early attempted to map the cortical representation of function in the human brain. Sherrington's influence is clearly evident in their maps. Upper. Mills and Frazier's map, 1905–1906. Middle. Cushing's map, 1907–1908. Lower. Krause's map, 1908–1911.



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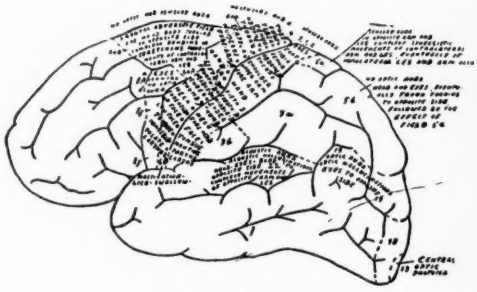

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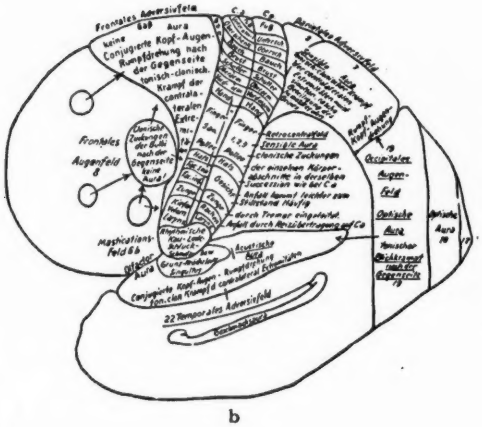

b

FIG. 63. a, Map of primary, secondary, and tertiary "cytoarchitectural" and physiologic fields of the monkey's brain prepared by Cecile and Oscar Vogt between the years 1906 and 1919.

b, Map of primary, secondary, and tertiary physiologic fields of the human brain described by Foerster in 1925 and 1926. These correspond closely to the cytoarchitectural and physiologic fields of the monkey's brain as defined by the Vogts (above).

c, Map of primary, secondary, and tertiary physiologic fields of the human brain reported by Foerster and Penfield in 1930 as the result of direct electrical stimulation of the exposed brains of 100 patients.

Between 1906 and 1919 Cecile and Oskar Vogt (481, 482, 483, 484) published a series of important papers describing a number of different "cytoarchitectural" fields in the cortex of the monkey to which they ascribed specific physiological functions (FIG. 63a). In addition to the "primary" fields already described by Ferrier, Horsley, and Sherrington, these workers described "secondary" and even "tertiary" cortical fields to which they ascribed localization of more complex and associated neurologic functions.

In 1926 Foerster (168) published a schematic map of the human brain (FIG. 63b) in which he indicated in considerable detail the location not only of "primary" but of "secondary" and "tertiary" fields, corresponding to those which the Vogts had described in the monkey, which he had identified by electrical stimulation of the human brain.

In 1930 Foerster and Penfield (174, 175, 359) published another map (FIG. 63c), based on electrical stimulation of the brains of 100 patients, reaffirming in considerable detail the localization of cortical centers which Foerster had described earlier.

Penfield (364), however, working with Boldrey, published in 1937 results of cortical stimulation which were at wide variance with those previously reported jointly by him and Foerster. In his 1937 map, Penfield discarded his earlier (horizontal) concept that the primary motor cortex was located entirely anterior to the central sulcus in the first precentral convolution; he described, instead, a "mixed motor-sensory cortex" with both motor and sensory representations occurring in both the precentral and postcentral convolutions (FIG. 64). He also discarded his earlier (vertical) concept of the orderly and constant representation of primary motor centers for the lower extremity upon the lateral surface of the cerebrum, with the centers for "toes, foot, tibia, femur, abdomen, and thorax" ar-

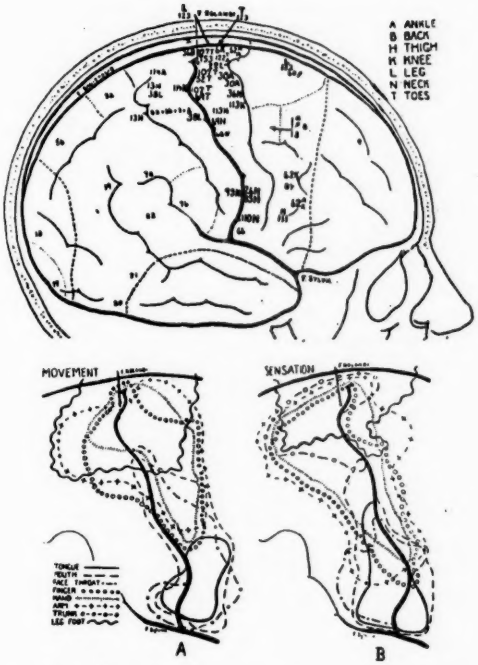

FIG. 64. Penfield and Boldrey's concept of cortical representation of function (1937).

Penfield has here discarded all of his previously reported localizations (Fig. 63c), and here describes a "mixed" motor-sensory cortex, with cortical representation of both motor and sensory functions assigned to both the precentral and postcentral convolutions. He has also here discarded his previously reported orderly, "scaling ladder" arrangement of centers for the various body-parts on the lateral convexity of the cerebrum, with the "centers" for the toes at the superior mesial border of the hemisphere, and the "centers" for the other parts of the lower extremities, trunk, thorax, upper extremities, and face arranged progressively on the lateral convexity of the cerebrum. In 1937 he also found a very mixed and inconstant "vertical" representation of these functions on the lateral surface of the hemisphere.

ranged serially from above downward; instead, he indicated irregular, inconstant representations of the motor centers for the lower extremity far down upon the lateral convexity of the hemisphere (FIG. 64).

In 1940 Scarff (407) published a "map" representing his contention, based on personal observations, that the primary motor centers for the lower extremity were not present at all on the lateral surfaces of the cerebrum but were located entirely on the mesial surface of the

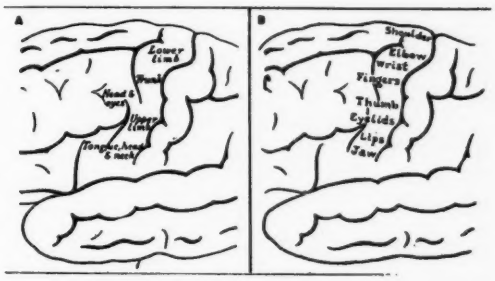

FIG. 65. The primary cortical centers for upper and lower limbs in man, as observed by Scarff (1940).

It had generally been accepted since Sherrington's time that in man, as is true in the higher apes, the cortical centers for primary movements of the toes, ankle, knee, hip, abdominal and thoracic muscles, and the corresponding axial muscles were situated in the precentral gyrus on the lateral surface of the cerebral hemisphere; the center for the toes was usually assigned a place at the superior margin of the hemisphere, extending somewhat over into the mesial surface of the brain, while the centers for other parts of the lower extremity have been represented as occurring in the order named, from above downward on the lateral convexity of the cerebrum (*A*). (See also Figs. 62a, b, c; 63b, c.)

Scarff's observations indicated that the centers governing primary movement of the upper extremity *in man* extend up to the superior border of the hemisphere and that the lower extremity is represented wholly on the mesial surface and is entirely unrepresented on the lateral surface of the hemisphere (*B*).

hemisphere (FIG. 65). Putnam (388), in 1942, confirmed Scarff's observations (FIG. 66).

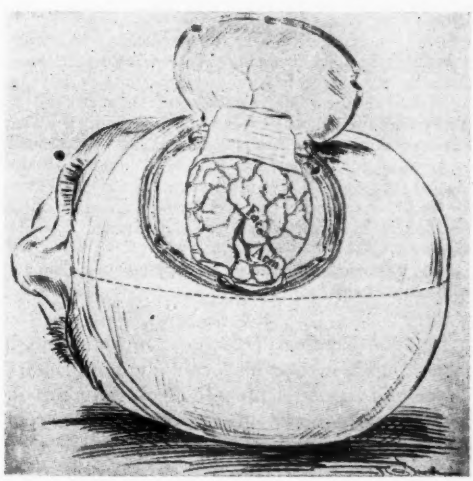

FIG. 66. Putnam, in 1942, confirmed Scarff's observations (see Fig. 65).

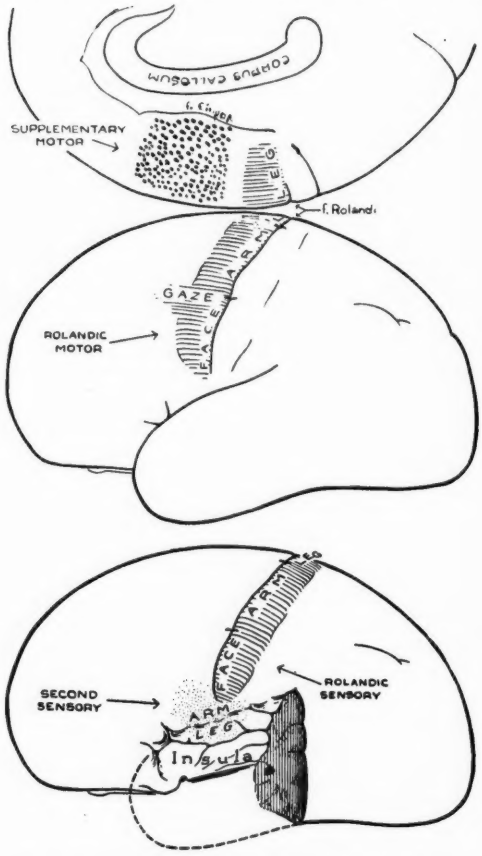

FIG. 67. In 1954 Penfield, collaborating with Jasper, again revised his localization of primary motor and sensory centers in the human cortex, reverting at this time to the "traditional" concept that the primary motor cortex lies anterior to the central sulcus and that the primary sensory function lies posterior to it. His 1954 map also indicated the localization of primary motor cortical centers for the lower extremity to lie on the mesial surface of the hemisphere, as described by Scarff and Putnam (Figs. 65b and Fig. 66).

Note Penfield's secondary, or supplementary, motor and sensory fields.

In 1954 Penfield (369), collaborating with Jasper, again revised his localization of primary motor and sensory centers in the human cortex, reverting once more to the "traditional" concept that the primary motor cortex lies anterior to the central sulcus and that the primary sensory function lies posterior to it, and indicating, also, the location of the primary motor cortex for the lower extremity to be on the mesial surface of the hemisphere (FIG. 67).

The number of hemispherectomies recently performed for the relief of intractable epilepsy has recalled to attention the fact that many of these patients, after operation, still retain an amazing voluntary control of movement and some localizing sensibility in their contralateral extremities (257, 274). This existence of focal representation of function in the subcortical and ganglionic regions of the brain has stimulated new investigation into the so-called "secondary" motor and sensory fields of Penfield (FIG. 67). These must not be confused with the other "secondary" motor fields described by Foerster (167, 168, 169) in 1925 and 1926 and by Foerster and Penfield (175) in 1930 after the cytoarchitectural fields originally (1919) found in animals by the Vogts (481, 482, 483, 484).

Recently attention has been directed to the "limbic system" of the brain. This is comprised of the great limbic lobe of Broca and its subcortical cell stations—the amygdala, the septal nuclei, the hypothalamus, the anterior thalamic nuclei, and parts of the basal ganglia. Broca first pointed out that the limbic lobe is the common denominator in the brains of all mammals. Experimental studies during the last 15 years indicate that this system participates richly in a great variety of viscerosomatic reactions (FIG. 68). Time does not permit an attempt to review the voluminous literature on this subject. Reference is made to the papers of Papez (354), MacLean (300), Penfield (369), and Pool (378).

An entirely new and different approach to "brain-mapping" was introduced into human surgery by Erickson (153) in 1946. He mapped the *sensory* cortex of the human brain by charting action currents recorded from the surface of the cortex in response to sensory stimuli applied to the patient's extremities.

The Surgical Treatment of Epilepsy

Because the motor area of the brain could be easily identified at the operating table, focal epilepsy early tempted the neurosurgeon to expose and remove the epileptogenic focus. Thus we find that the first operation (May 25, 1886) performed by Horsley (242) was for the removal of a cortical scar caused by an old depressed fracture which gave rise to convulsions beginning in the right leg. The scar was excised and the patient made a good operative recovery. The fact that during

the 13 days immediately prior to operation the patient had experienced 2,870 fits, whereas during the 11 months following the operation (extending up to the date the report was published) he had had no attacks, did much to stimulate surgical efforts to relieve focal epilepsy. By December, 1886, Horsley himself had operated upon 8 patients with fits, some due to scars following fractures of the skull, some due to old hemorrhages, and some due to tumors.

In 1888 Keen (258) operated upon a young man having fits beginning in the left hand. Upon exposing the cortex he found no discernible lesion, but he identified the "hand center" by electrical stimulation and excised it. The patient recovered, with a persistent partial paresis of the hand but with a marked reduction in fits.

In 1893 Starr (448), in his book on "Brain Surgery," devoted one entire section to surgical treatment of focal epilepsy. He gave case histories of 42 patients collected from his own experience and from the literature, who had been operated upon for relief of focal epilepsy with the following results: 13 cured, 11 benefited and 15 not benefited; there were 3 operative deaths. Ten of these patients had been operated upon by MacBurney of "appendectomy" fame and the others by 7 other general surgeons. Starr concluded his chapter on "Trephining for Epilepsy" as follows:

> Shall we continue to trephine any cases of traumatic or localized epilepsy?
>
> Judging by general results which are unfavorable, we should be inclined to stop. But when it is taken into consideration that in no case is it possible without an operation to determine the exact pathological condition present, and that a certain proportion of the pathological conditions are removable, it is evident that an operation if not attended with danger may be reasonably undertaken. Some patients have undoubtedly been cured.

Cushing, presumably because of his preoccupation with brain tumors, apparently showed little interest in the surgical treatment of epilepsy, for we find the terms "convulsion" or "epilepsy" appearing only three times in his extensive bibliography and these were in reports of patients with gross lesions of the cortex.

Frazier (181) in 1921 made his only contribution to the surgical treatment of epilepsy by describing his personal experiences with 63 patients, 53 of whom he had operated upon. The causes of the convulsions in these patients included fracture of the skull, cerebral contusion, intracranial hemorrhage, tumor, and meningitis; in 10 cases the etiology was undetermined. The operations included craniotomy plus decompression, evacuation of cysts, removal of clots, and in one instance the removal of a normal-appearing "facial center." Seven of the 53 patients (13%) were benefited.

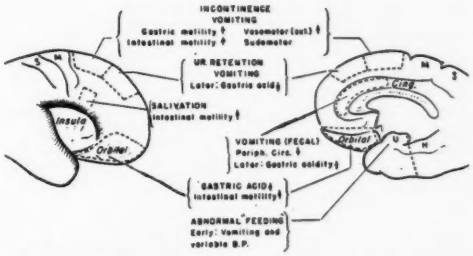

FIG. 68. A "map" of the limbic system of the human brain showing the focal representation of various visceral reactions as determined by Pool (1954).

In his monumental work on "Surgery of the Brain," in three volumes published in 1911, Krause (273) devoted more than 200 pages to the subject of epilepsy and its surgical treatment. He reviews the earlier work of Hitzig, Ferrier, Sherrington, and Grünbaum; discusses electrical stimulation of the brain; reports his own "map" of excitable foci; and discusses the "anatomic proof of the exclusive irritability of the anterior central convolution." He also discusses focal epilepsy in its various forms, defining jacksonian epilepsy accurately as opposed to other focal epilepsies. He considers the etiology of jacksonian epilepsy, beginning with tumors and ending with "jacksonian epilepsy without anatomic findings." He discusses the results of cortical excisions both upon the course of the disease and upon the general neurologic status of the patient. He presents in great detail the case reports of 21 patients with focal epilepsy who were operated upon by him. The findings at operation in every instance are represented by excellent pictures, many in color. The tissues removed were studied and reported on by Vogt or Brodman.

Krause's results are here given:

> My experience with Jacksonian epilepsy dates back to 1893. I have kept many patients under continuous observation and have later corresponded with them or their relatives with reference to condition. Patients of the Berlin Hospital are frequently a traveling lot from whom nothing more is heard after they are gone; consequently I could not obtain any data from these people. I therefore felt obliged to mark all of that class as not cured. In tabulating my results I strictly de-

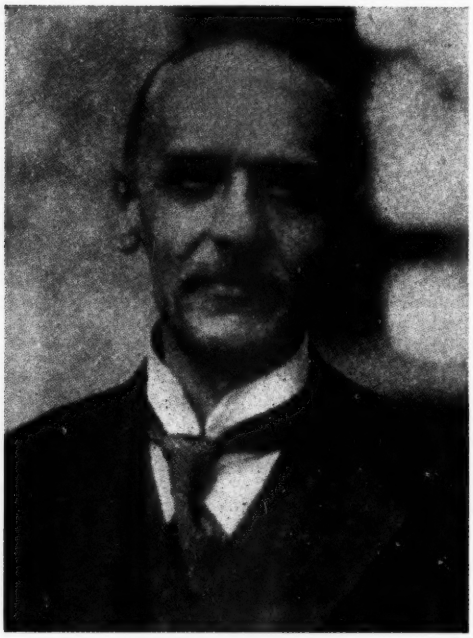

FIG. 69. Otfreid Foerster.

sisted from over-enthusiasm; on the contrary, an element of pessimism was always before me.

Of a total of 49 cases operated upon for Jacksonian epilepsy only one died [4 per cent operative mortality] immediately following the operation: three other patients, 8, 28 and 38 years of age, succumbed in status epilepticus, 3, 5 and 6 days respectively after operation [10 per cent case mortality]. . . . All other patients recovered.

Question sheets were sent out about the time of completing this book (October 1910). . . . Of the 29 patients who answered, 11 find their condition the same as before the operation; 3 became aggravated; and in 8 [16 per cent of total series] a marked improvement has taken place; in 2 cases nearly a year has passed since the operation, and in the others 2 to 5 years have gone by. Very good results were obtained in 3 cases [6 per cent of entire series]; . . . I consider 4 cases [10 per cent of series] completely cured.

Prognosis is uncertain even in typical cases of Jacksonian epilepsy. We cannot even promise an improvement with entire certainty. I invariably refuse to operate when assurance or guarantee is wanted. How dare we even think of making definite promises in these cases when the extent and nature of the cortical changes are entirely unknown to us until the patient is operated upon?

Foerster (FIG. 69), unquestionably stimulated by the Vogts' identification of primary and secondary cytoarchitectural and physiological fields in the monkey, soon after began intensive and sustained efforts to identify similar fields in man, and to use this new knowledge for the localization and excision of epileptogenic foci. In 1925 a comprehensive paper on the pathology and surgical treatment of epilepsy (167), and the following year two more important papers, one on the pathology of epileptic convulsions (168) and the other on the surgical treatment of epilepsy (169), were published by Foerster. In 1930 (174, 175) he published, with Penfield, two papers, one in German and one in English, on the structural basis of traumatic epilepsy and the results of radical operation. In these interesting and valuable papers the authors express their opinion that cortical scars producing convulsions should be treated by block excision of the scar and immediately adjacent cortex straight into the ventricle; by so doing a porencephalous cavity filled with cerebrospinal fluid in free communication

TABLE IX.—RESULTS OF CRANIOTOMY FOR EPILEPTOGENIC ATROPHIC CEREBRAL LESIONS AS REPORTED BY PENFIELD (1941)(366)

	Meningocerebral cicatrix excision			*Cerebral cicatrix excision*			*Exploration without excision*		
Result groups	*Number of patients*	*Per cent*		*Number of patients*	*Per cent*		*Number of patients*	*Per cent*	
Complete freedom from attacks	14	22.5	45	10	19	40	1	2.5	5
Seventy-five per cent improved or better	14	22.5		11	21		1	2.5	
Fifty per cent improved	20	32		10	19		7	20	
Slight improvement	6	10		5	9		0	9	
No change	7	11		16	30		24	69	
Worse after operation	1	2		1	2		2	6	
Total	62	100		53	100		35	100	
Removal of cicatrix				115					
Control group of negative explorations				35					
Ligation of cortical artery				5					
Cases with inadequate follow-up				3					
Operative deaths				7		Operative mortality 4.2 per cent			
Total number of cases				165					

with the ventricle is left in place of the original scar, rather than a new cavity in the cortex which will fill up again with a fresh progressively contracting and irritating cicatrix. The authors reported 12 patients so treated with good results.

Penfield, since 1924, has devoted most of his energies to a sustained study of the pathology and surgical treatment of epilepsy, and unquestionably has made more contributions to this subject than any other neurosurgeon. In 1924 he published a paper on meningocerebral adhesions (356); in 1927 on the mechanism of cicatricial contraction in the brain (357); in 1929 (358) and again in 1930 (360) on diencephalic autonomic epilepsy; in 1930 (359) on the radical treatment of traumatic epilepsy; in 1933 (361) on the evidence for a cerebral vascular mechanism in epilepsy; in 1936 (362) on epilepsy and surgical therapy; in 1938 (363) on the circulation of the epileptic brain; in 1939 (365) on the radical treatment of the epilepsies, on the cortical spread of epileptic discharges, the conditioning of habitual seizures, and on the cerebral blood flow during induced epileptiform seizures in animals and man; and in 1940 (368) on electroencephalography in focal epilepsy, and on focal epileptogenic lesions of birth and infancy (370).

In 1941 Penfield and Erickson (366) published an exhaustive treatise on "Epilepsy and Cerebral Localization" in which they reported results of excision of meningocerebral and cerebral cicatrices in 115 patients suffering from posttraumatic epilepsy. These are condensed in Table IX. In their volume Penfield and Erickson give no case records nor results from excision of epileptogenic foci other than those associated with gross cortical or meningocortical cicatrices.

Walker (485) in 1949, in a small but meaty little monograph on "Posttraumatic Epilepsy," reported his observations on 238 cases of posttraumatic epilepsy under his care at the Cushing General Hospital, United States Army, during and immediately following World War II. In this

TABLE X.—RESULTS OF MEDICAL THERAPY IN CUSHING HOSPITAL SERIES—POSTTRAUMATIC EPILEPSY, AS REPORTED BY WALKER (1949)(485)

(Approximately one year after discharge)

Patients discharged as controlled	130
No convulsions	51 (55.5 per cent)*
One convulsion	19
Several convulsions	22
Number working	28 (31.8 per cent)
Patients with inadequate hospitalization	42
Patients not controlled medically	66
Total	238

*Calculated on the follow-up study of 92 cases.

total group 40 patients were subjected to surgical removal of epileptogenic foci. Approximately one year after operation 33 per cent of the patients treated by cortical excision had had no further attacks and another 20 per cent had had only one attack. In a control group 15 per cent had one or no attacks. Walker's observations are condensed in Tables X and XI.

Subpial resection of cortical gyri (Horsley's operation) for the relief of Jacksonian epilepsy in 66 cases was reported in 1935, by Sachs (402). Some patients had gross cortical scars; some did not. The results were better when no gross cortical scar was present.

A specific epileptic syndrome favorably affected by "lysis" of anomalous pacchionian granulations was described by Scarff (405) in 1936. The syndrome occurs in children during the first or second decades and consists of clinical evidence of a chronic focal irritative lesion situated near the superior end of the primary motor strip on the lateral surface of the cerebrum; it is associated with an essentially normal neurological examination and pneumoencephalogram. Exposed at operation, the cortex appears normal except for the presence of a large abnormal pacchionian granulation situated on, or immediately adjacent to, the primary motor cortex. Electrical stimuli of minimal physiologic strength yield focal responses from all points except in the

TABLE XI—RESULTS FROM CORTICAL EXCISIONS—POSTTRAUMATIC EPILEPSY AS REPORTED BY WALKER (1949)(485)

(Approximately one year after operation)

	Scar resection	*Scar resection to ventricle*	*Epileptogenic focus*	*Subdural membrane*	*Total*	*Control group*
No attacks	2	3	7	0	12	1
Aura only, or one attack	1	1	4	1	7	2
Major attacks	6	3	7	1	17	17
Total	9	7	18	2	36	20

TABLE XII.—RESULTS OF PARTIAL TEMPORAL LOBECTOMY ON TEMPORAL LOBE EPILEPSY AND ON ELECTROCORTICAL ACTIVITY, AS REPORTED BY BAILEY AND GIBBS (1951)(17)

Anterior temporal spikes (Postoperative EEG)	*Therapeutic effect on psychomotor seizures*			
	Great	*Moderate*	*Slight*	*None*
Absent or greatly reduced	5	4	0	0
Moderately reduced	0	3	4	0
Slightly reduced	0	0	2	1
Not changed	0	0	1	5
Total	5	7	7	6

vicinity of the granulation, where they set off focal convulsion similar to the clinical seizure. Division of this anomalous pacchionian granulation results in marked reduction of the convulsions.

Total unilateral cerebral hemispherectomy for the treatment of intractable epilepsy was described in 1950 by Krynauw (274), who reported at that time his results in 12 cases so treated. Total unilateral hemispherectomy in an effort to cure gliomas had already been reported by Dandy (124, 130) (1928), Gardner (203) (1933), and Karnosh and Gardner (257) (1940), and others. In 1939 Williams and Scott (498) mentioned that McKenzie in 1938 had performed a cerebral hemispherectomy in an attempt to control convulsive seizures. There were, however, no other reports of this procedure being done for the relief of epilepsy until November, 1950 when Krynauw in his classic paper described 12 cases in which he had performed this operation. All of the patients were children who had long suffered with infantile hemiplegias associated with uncontrollable convulsions. Among Krynauw's 12 patients there was one operative death; in all of the others the epileptic manifestations ceased immediately after operation and remained absent. The return of motor power following operation was a striking feature in his cases. Marked improvement in mentality and behavior was also noted in Krynauw's cases.[16] Since Krynauw wrote his paper, others (47, 197, 299, 304, 344, 343, 384) have reported limited experience with this procedure.

Psychomotor epilepsy was first established as a clinical entity in 1947 by Fuster and Gibbs (202), and in 1948 a fuller description (205) of the same syndrome was given by them. In November, 1948 Bailey and Gibbs (16) presented a preliminary report on the therapeutic results of temporal lobotomy for psychomotor epilepsy. In February, 1951 they presented a more comprehensive paper (17) reporting results obtained by them following excision of the anterior portion of one temporal lobe in 25 patients operated upon by them for this condition. These results are presented in Table XII.

In the meantime, following Bailey and Gibbs' initial report, Penfield and Flannigan (367), Morris (332), and Greene *et al.* (215) published results of their experiences in this field. Since that time increased interest has developed in this subject and literature too voluminous to refer to here in detail has been published. These reports contain slight modifications of the original operative technique without, however, any change in principle. Reports indicate that this type of epilepsy is far more common than originally thought.

In 1954 Penfield (369) with Jasper published a second comprehensive volume on "Epilepsy and the Functional Anatomy of the Brain." In this book the authors do not add any additional data upon the effect of excision of gross meningocortical or cortical cicatrices beyond the 115 cases previously described by Penfield and Erickson (366) in 1941 (Table IX) and the 75 additional

[16]The remarkable recovery of voluntary motor and sensory functions in the contralateral extremities following total hemispherectomy implies focal representation of these functions below cortical levels within the basal ganglia. This has opened up fresh physiologic explorations of the brain which have already been briefly reviewed.

TABLE XIII.—RESULTS OF 75 OPERATIONS FOR RELIEF OF CEREBRAL SEIZURES, PERFORMED BETWEEN 1939 AND 1944, AS REPORTED BY PENFIELD AND STEELMAN IN 1947(369)

Operation	*Complete freedom from attacks*	*(75%) Improvement or better*	*(50%) Improvement*	*Slight improvement*	*No change*	*Total cases*
Cortical excision						
No. of cases	15	18	8	7	11	59
Percentage	25.3%	30.5%	13.6%	12%	18.6%	
		55.8%				
Craniotomy without excision						
No. of cases	0	0	5	2	9	16
Percentage			32%	14%	54%	

cases previously reported by Penfield and Steelman in 1947 (369) which are condensed in Table XIII. They do not report any experiences with excision of purely "physiologic" epileptogenic foci unaccompanied by gross lesions on the lateral aspects of the cerebral cortex. However, they do give full reports of 68 new cases in which the anterior portions of the temporal lobes were resected by Penfield for the relief of temperal lobe epilepsy. Their valuable observations are too numerous to describe in detail in this text, but those interested should refer directly to this imposing treatise. Their results in condensed form are given in Table XIV from Penfield and Jasper's book.

TABLE XIV.—RESULTS OF 51 TEMPORAL EXCISIONS FOR RELIEF OF TEMPORAL LOBE EPILEPSY, AS REPORTED BY PENFIELD AND JASPER (1954)(369)

(One to 10 years after operation)

Result	Number of cases	Per cent	Per cent	
No improvement	7	13.7	21.5	"Failure"
Slight improvement	4	7.8		
"Improved 50 per cent" or more	13	25.4	25.4	"Worth while"
"Cured"—one or more attacks before cessation	13	25.4	52.8	"Success"
"Cured"—no attacks	14	27.4		
Total	51			

An important paper inquiring into the current premises, their implementation, and the criteria employed in reporting results of surgical treatment of focal epilepsy was published in 1954 by Meyers (316). In this paper Meyers reported results of extirpation of presumed epileptogenic foci in a series of 93 patients operated upon by him during the past 15 years and followed up for a minimum period of 5 years. The measures which he employed during operation to decide which areas of the cortex constituted "firing points" were as follows:

Inspection and palpation alone	15
Stimulation alone	7
Inspection, palpation, and stimulation	52
Electrocorticography alone	5
Stimulation and electrocorticography	8
Inspection, palpation, stimulation, and electrocorticography	6
Total	93

The operative mortality for the 93 patients was 6.2 per cent and the known case mortality 12.3 per cent. The follow-up studies were considered to be compromised in 12 instances. Only 11 per cent of the remainder of the patients have remained "seizure-free" for 5 or more years and an additional 24 per cent showed benefit from the operation. The figures were submitted with full recognition of their necessarily tentative character.

Meyers concluded a critical review of the surgical treatment of epilepsy as follows:

> This general review prompts serious inquiry into the conceptual basis of the current day surgery of focal epilepsy. That the so-called epileptogenic focus necessarily initiates and/or mediates clinical seizures appears to be a concept, rather than an established fact. The utilization of the concept at the operating table entails the adoption of a number of subsidiary assumptions, such as that of the electrocorticographic "spike" as an indicator of the focus responsible for recurrent seizures. While proof of the validity of these prime and subsidiary concepts is lacking, conclusive arguments to the contrary are at present also lacking. Some evidence is at hand to suggest that multiple foci rather than a single focus may characterize "focal" as well as "petit mal," "grand mal" and "psychomotor" epilepsy.
>
> Examination of representative series in the literature reveals wide disparities in diagnostic material, numbers of cases, criteria adopted for selection of cases, preoperative work-up, surgical measures employed, follow-up period and manner of evaluating results. Comparisons from series to series, with a view to deciding the relative merits of the various diagnostic and therapeutic measures employed, do not, as of the present, promise to yield useful data.
>
> Meyers makes a plea for widespread adoption of uniform criteria setting forth the precise conditions under which cases may properly be classified as "seizure-free," and "improved." This would make possible a meaningful comparison from series to series and so quicken the progress in this special field of neurologic surgery.

Electroencephalography and Electrocorticography

As early as 1874 Caton (51) discovered that there were changes in electrical potentials in the living brain, which he regarded as related to nervous function. In 1902 Berger (27) recorded potentials from the brains of animals, but it was not until much later that he began intensive work on this subject. In the meantime the string galvanometer had been developed and in 1925 Neminski (337) used this instrument for recording the electrical activity on the dog's cortex. In 1929 Berger (27) began the publication of a series of reports on the brain waves of man. At first his findings were regarded with incredulity, but others rapidly took them up and by 1939 an entirely new specialty had developed. The Gibbses and Lennox (206) found electroencephalography ideal for the study of epilepsies, and Walter (492) illustrated its value in the

localization of brain tumors. Although Berger was the first to obtain samplings of electrical activity directly from the exposed human cortex, the first serious study of this sort was made in 1935 by Foerster and Altenburger. They showed in that year that a tumor exposed at operation had no electrical activity, but that compressed or infiltrated cortex at the margin was characterized by abnormally slow waves. This problem was further studied by Walter (493). The cortical activity of the epileptic brain was first sampled in 1940 by Scarff and Rahm (419, 420), who coined the word "electrocorticogram." The spontaneous electrical activity arising in the subcortical areas of the brain was first studied with a "depth electrode" devised by Haynes (226) and Spiegel (437).

Relief of Pain

The first neurosurgical operations performed for the relief of pain were those directed to the relief of trigeminal neuralgia. A full account of the evolution of trigeminal surgery has been recounted in preceding pages.

The second neurosurgical procedure devised purely for the relief of pain was *posterior rhizotomy*, first proposed by Dana (111) in 1886 and first performed by Abbe (1, 5), his surgical colleague, later in the same year. Spiller has erroneously been credited with first suggesting dorsal root section for the relief of pain and Frazier with having first performed it, as the result of a report by them on this subject in 1910. But Frazier first operated upon his patient in 1910 and reported his case in the same year. In that report he stated that Spiller had first suggested the operation to him in 1905. Priority for this procedure belongs to Dana and Abbe.

Cordotomy or, more correctly, surgical section of the anterolateral spinothalamic tracts, for the relief of pain in the lower parts of the body and in the lower extremities was first proposed by Spiller (440, 441) in 1905 as the result of a most astute observation on his part. He had for some time carefully studied the unusual neurological deficits of a patient with disseminated tuberculosis, and had observed that this patient had lost the sense of pain and temperature in his lower extremities without having lost tactile sense, kinesthetic sense, or motor power. Entirely on the basis of these clinical observations Spiller hypothecated that the patient had two small, symmetrically placed, bilateral tuberculomas of the spinal cord so situated as to interrupt the anterolateral spinothalamic tracts on each side of the cord. This patient eventually died and at autopsy the findings were precisely those predicted by Spiller (Fig. 70). Spiller then persuaded his colleagues, Cadwalader and Sweet (44), to section these tracts in dogs, and observed that postoperatively they apparently experienced no pain in their lower extremities. Further stimulated by this laboratory study confirming his earlier clinical observations, Spiller (446) in 1911 persuaded Martin, Professor of Surgery at the University of Pennsylvania, to perform this operation on a patient suffering great pain from a pelvic carcinoma.

Martin performed the first cordotomy on January 19, 1911. In his operative note he stated that: "The surgical task assigned to me by Professor Spiller was to make a transverse cut into the spinal cord roughly 2 mm. in length, of similar depth, and with its posterior end 3 mm. anterior to the entrance of the posterior root, this cut to be bilateral." The operation was successfully performed, and postoperatively the patient experienced partial relief from his pain. The fact that he did not experience complete relief was undoubtedly due to the fact that Martin's cuts were not quite deep enough so that the upper level of cutaneous analgesia, as determined postoperatively by Spiller, extended upward only as far as the first lumbar dermatome bilaterally.

In 1912, a few months after Martin's operation, Beer (25) cut the anterolateral tracts for intolerable pain of metastases in the sacral plexus. A few months still later, in 1913, Foerster (166), quite unaware of Martin's and Beer's operations, reported that in December, 1912 he and Tietze had sectioned the anterolateral tracts in a patient for relief of tabetic pain.

It was not until 1920, 8 years later, that Frazier (186), who is generally accredited with having first performed this operation, published his first paper on this subject, reporting his first 6 cordotomies. It is curious that in his report, Frazier makes no mention of the fact that this operation had been first performed by Martin, a colleague in his own hospital, and also by Beer and Foerster, nearly 8 years before. He stated:

> In 1912 Spiller proposed section of the anterolateral columns of the cord, when for one cause or another the patient is suffering from intractable pain. Since that time I have carried out this operation on 6 oc-

casions; in 4 there was complete, and in 2 partial, relief.

Frazier undoubtedly popularized cordotomy, and this operation has remained one of the principal mainstays in the neurosurgical relief of pain; several minor technical refinements in the performance of the operation have been suggested from time to time by various workers since Spiller and Martin's first case, but the basic principle and technique have remained essentially unchanged. These various considerations are fully reviewed by White and Sweet (496) in their comprehensive book on pain.

Stookey (459, 461) in 1929 stated that he had attained analgesia without thermoanesthesia by making a delicate lateral incision just ventral to the dentate ligament and bringing the knife out just lateral to the anterior horn.

Posterior chordotomy, or section of the dorsal columns of the cord, was performed for the relief of phantom limb pain by Pool (376) in 1946 and by Browder and Gallagher (39, 40) in 1946 and 1948, in cases in which the patient felt that the phantom limb was being twisted or placed in an uncomfortable position. The results were good in properly selected cases.

Because cordotomy, even when performed in the high cervical region, did not always relieve pain in the shoulder and neck, various surgeons have developed operations for cutting the spinothalamic tract at higher levels within the brain stem. In 1941 Schwartz and O'Leary (422) divided the tract at the level of the inferior olivary nucleus; Dogliotti (142, 143) in 1938 reported section of the spinothalamic tracts at the upper border of the pons. Walker (486), on the basis of neuroanatomic and surgical considerations, proposed and carried out section of pain fibers at the mesencephalon, an operation known as "mesencephalic tractotomy." Spiegel, Wycis, Freed, and Lee (437) described placing electrolytic lesions along offending pain-conducting pathways of the midbrain and thalamus by means of a stereoencephalotome. This operation they termed "thalamotomy."

In 1942 de Gutierrez-Mahoney (218) resected the presumed postcentral cortical representation of the painful phantom limb. The relief of pain following the operation, however, was incomplete.

In 1942 Freeman and Watts (194) made the isolated remark that psychosurgery would relieve mental pain. About the same time Van Wagenen (478) performed a frontal lobotomy on a psychotic individual who suffered from a painful phantom limb. Following the operation the patient no longer complained of the pain. In 1945 and 1946 Freeman and Watts (195) published a series of articles on the relief of pain of organic disease by frontal lobotomy. At the 1947 meeting of the Association for Research in

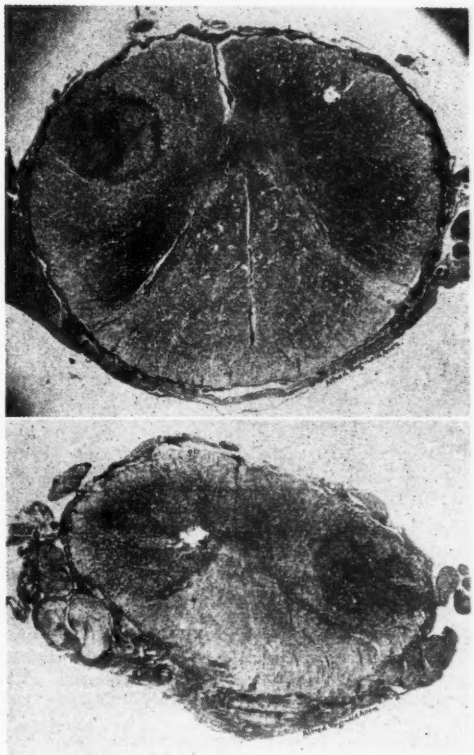

FIG. 70. The origin of "cordotomy."

Cross section of the spinal cord of a man who had suffered during his life from diffuse tuberculosis. Spiller observed, before this patient died, that he had lost pain and temperature sense in the lower extremities but had retained tactile and position sense as well as motor power. On the basis of these neurologic observations, Spiller made the remarkable clinical diagnosis of the existence of two symmetrically placed bilateral tubercles interrupting the right and left anterolateral spinothalamic tracts, a diagnosis strikingly verified at autopsy, as the above illustrations show.

On the basis of these observations Spiller, in 1905, proposed elective surgical section of the anterolateral spinothalamic tracts (cordotomy) in man for the relief of somatic pain.

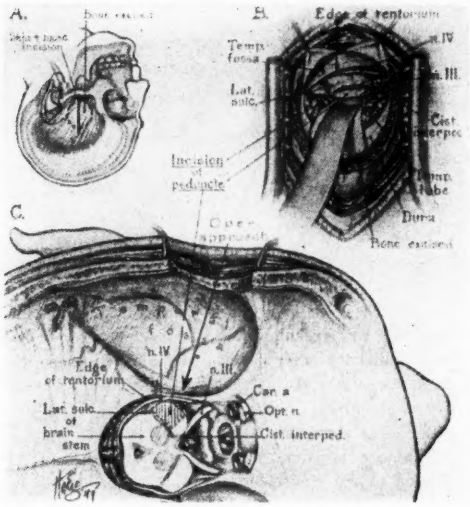

FIG. 71. Treatment of hemiballismus by Walker's (1948) "cerebral pedunculotomy."

The operative approach for section of the cerebral peduncle is indicated.

A. The head hangs down to allow the temporal lobe to fall away from the floor of the middle fossa.

B. By gentle retraction the incisura tentorium is exposed and the arachnoid is incised over the brain stem. The peduncle is well visualized and the incision made from the lateral sulcus medially.

C. A sketch to show the relations in the operative field.

Nervous and Mental Disease, Koskoff *et al.* (269) stated that some of the distressing sequelae of frontal lobotomy were lacking if only a unilateral leucotomy was performed and that the latter was adequate to relieve pain. In the following year (1948) Scarff (410, 414) reported the relief of ipsilateral, contralateral, and bilateral pain by unilateral prefrontal lobotomy. Later, in 1949, Scarff (411) reported 33 cases of unilateral prefrontal lobotomy performed for the relief of pain due to organic causes. In 22 of the cases (66 per cent) results were classified as good as the patients no longer complained of pain or requested medication after the operation; the results in 6 cases were classified as fair in that the patients still complained somewhat of pain but were made comfortable with very much smaller amounts of analgesic drugs than were required preoperatively; in 5 of the patients (15%) the results were classified as poor in that no relief whatever from the pain followed the operation. An effort was made by Scarff (411) to determine the effect of the operation upon the intellect and personality, and it was his conclusion that no clinically significant alteration in either resulted from the unilateral operation. Scarff also observed that, following unilateral lobotomy, it was possible to terminate narcotic addiction due to pain abruptly without clinically significant evidence of the physical and emotional disturbances commonly associated with the termination of such addiction. In 1950 (414) he reported the results in 58 cases.

Surgical Treatment of the Dyskinesias—Athetosis, Hemiballismus, and Dystonia Musculorum Deformans

As early as 1909 Horsley (245) removed the cortical centers for the upper extremity to relieve *athetosis*. Following operation the patient was free of the involuntary movements but had a persistent monoparesis of the previously affected extremity. In 1932 Bucy and Buchanan (42) excised the cortical representation for the wrist and fingers in the hope of relieving athetosis of the contralateral upper extremity. Following the operation the athetosis was abolished and never recurred. Immediately following the operation the patient was unable to flex the left elbow or move the left wrist or finger; he could, however, extend the elbow and abduct the arm at the shoulder. A week later he could flex the elbow, and 4 days later he could supinate and pronate the forearm. He was never able, following the operation, to move the left wrist or fingers. The patient had numerous convulsive seizures following the operation which were still recurring, despite medication, one year later.

In 1935 Sachs (402) reported subpial resection of areas 4 and 6 of the cortex in 3 patients suffering from athetosis of a single upper extremity. In each of these 3 cases athetoid movements ceased with the operation, but in each instance there was a complete paralysis of the previously affected extremity which persisted.

In 1933 Putnam (385) treated 2 patients with choreoathetosis by interrupting the extrapyramidal tracts by section of the anterior columns of the spinal cord. He reported a decrease in the abnormal movements and only mild signs of pyramidal tracts with no permanent ill effects.

Hemiballismus, a clinical condition in which continuous, involuntary movements involve an entire extremity or part of the body with considerable violence, has also been a subject of neurosurgical attack.

In 1950 Meyers, Sweeney, and Schwidde (320) reported a case in which, after identification of the motor cortex by stimulation, an incision was made between area 4 and 4a on the side opposite the involved limbs; the cut was made 2.5 centimeters deep and extended 6 centimeters from the midline; this section was designed to interrupt the "U" fibers connecting areas 4 and 6. Ballismic movements were absent immediately after the operation and throughout the remainder of the patient's postoperative course. A left flaccid areflexic hemiplegia was present following recovery from anesthesia with temporary jacksonian convulsions for 4 days. The patient was stuporous for the better part of a week. During the third postoperative week the patient at times seemed bewildered; her speech was irrational. On the seventeenth day the patient executed weak movements in the left lower extremity, but otherwise the left hemiplegia persisted. On the twenty-sixth day following operation she developed bronchopneumonia and 3 days later she died.

In 1948 Walker (488) cut the lateral part of the left cerebral peduncle (cerebral pedunculotomy) (FIG. 71) for the relief of hemiballismus in one patient. The operation immediately and permanently abolished the severe involuntary movements, although a few jerkings were seen at times in the right hand. The strength in the right upper extremity was approximately 15 per cent less than in the left, as measured by the dynamometer. Co-ordination tests were all well performed, even fine movements. Station and gait were normal. The patient when last seen was carrying on her normal housework.

The most recently reported operation for hemiballismus was that of Brown and Walsh (41); their patient was a 73 year old man with a hemiballismus of violent degree on the left side. A combined suboccipital craniotomy and upper cervical laminectomy was performed and the cord was exposed at the level of the second cervical segment. Incision for a left ventrolateral tractotomy was made beginning exactly at the point of attachment to the dentate ligament and extending 4.5 millimeters in depth in transverse direction and emerging 2 millimeters ventral to the motor root. Following the operation the patient was free of ballismus and had no impairment whatever of voluntary movement. Unfortunately, he contracted pneumonia and died on the fifth postoperative day.

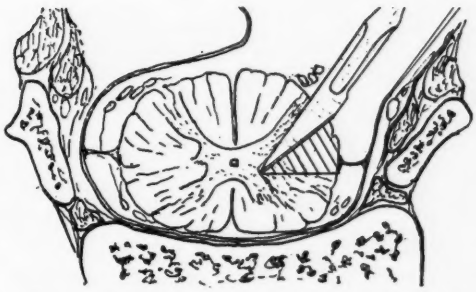

FIG. 72. Treatment of parkinsonism by section of the lateral pyramidal tract as advocated by Putnam (1940).

Dystonia musculorum deformans is the most distressing of all the types of involuntary motor disorders and raises the question as to whether the people described in the Bible as "possessed of the devil" were not, in reality, victims of this terrible affliction.

Few attempts at surgical relief of this condition have been made. In 1933 Putnam (385) performed upper cervical extrapyramidal tractotomies in 2 cases with poor results. Walker (487) in 1944 reported removal seriatim of the motor and premotor face and arm areas bilaterally in a case of severe dystonia with only temporary modification of the abnormal movements.

In 1953 Hamby (221) published an important communication on this subject in which he reported operative results in 5 cases. In case 1, he performed gross removal of area 6, followed in a second operation by removal of area 4; in case 2 he performed gross removal of the precentral gyrus alone; and in cases 3, 4, and 5 he performed partial bilateral cerebral pedunculotomy. Hamby supplies detailed case reports. His conclusion was that the results were more favorable and the side effects less disabling following the pedunculotomy than following cortical operations. This, it is important to note, is in agreement with the experiences of Walker and of Brown and Walsh in treating hemiballismus.

Surgical Treatment of the Dyskinesias—Parkinsonism

A variety of operations have been undertaken during the last 25 years for the relief of *parkinsonism* (paralysis agitans). Bucy (42) in 1932 extirpated portions of the cortex of the premotor and motor areas in 2 patients with tremor; effectual relief from tremors was obtained although

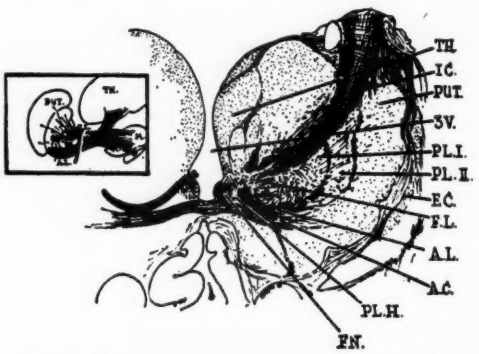

FIG. 73. Treatment of parkinsonism by section of the pallidofugal fibers as described by Meyers (1942). Semidiagrammatic cross section of the basal ganglions at the level of the anterior commissure just rostral to the foramen of Monro. The broad line represents the horizontal plane of incision intended to interrupt the ansa lenticularis. *Insert.* A longitudinal schema of the pallidofugal fibers. The broad line represents the vertical plane of incision intended to interrupt the fasciculus lenticularis and the "fine fibers" of Papez.

Abbreviations are as follows: *A.C.*—anterior commissure; *A.L.* — ansa lenticularis; *E.C.* — external capsule; *F.L.*—fasciculus lenticularis; *FN.*—fornix; *I.C.*—internal capsule; *M*—midbrain; *PL.I*—globus pallidus, crus I; *PL.II*—globus pallidus, crus II; *PL.H.*—pallidohypothalamic fibers; *PUT.*—putamen; *TH.*—thalamus; *3V.*—third ventricle.

a degree of paresis and a considerable dyspraxia in the affected limbs supervened.

In 1933 Putnam (385) reported sectioning of the extrapyramidal tracts in the spinal cord in 5 cases, encountering disappointment; he then, in 2 cases of hemiparkinsonism, sectioned the pyramidal tracts at the upper cervical level with gratifying improvement in both of these cases and (of especial interest) with survival of functions in the involved limbs which traditionally have been imputed to the pyramidal tracts (FIG. 72). Putnam (389) subsequently (1950) reported the results of 22 spinal pyramidotomies performed by him for the relief of parkinsonism with complete disappearance of the tremor in 33 per cent, marked reduction in an additional 33 per cent, and failure in 33 per cent. He reported "reduction of motor strength present in all cases immediately after operation subsided in the majority of cases but was still demonstrable to smaller and larger degree in some cases."

In 1940 Meyers (317) reported 3 instructive cases in which he operated for the relief of parkinsonism. In the first case he had transected the "U" fibers coursing between cortical areas 4 and 6 without alteration in the tremors; this was followed by undercutting of the entire premotor area, without effect on the tremors; and, finally, by an approach through the lateral ventricle, he exposed and excised the anterior two-thirds of the head of the caudate nucleus, this time with abolition of the tremors. The second patient, following extirpation of the head of the right caudate nucleus, had temporary cessation of the tremors of the left extremities. In a third patient in whom the entire head of the caudate nucleus was extirpated there was complete arrest of the tremors; this was accompanied by hemiparesis, which, however, gradually cleared up. In 1942 Meyers (318, 319), in a comprehensive review of the entire subject, reported 5 additional cases in which he had subjected the patients to various operations at the level of the basal ganglia. In this paper Meyers first reported section of the pallidofugal fibers (FIG. 73), which he had then performed in 3 patients, and came to the conclusion that this was the most effective measure of all which he had employed for the relief of parkinsonism.

Browder, on whose service Meyers had performed the pallidofugal sections, was, however, of the opinion that this operation was attended by too many undesirable side effects to remain an operation of choice for the treatment of parkinsonism. Furthermore, he came to the conviction that it was damage to the fibers of the anterior limb of the internal capsule that had produced the modifications of the tremor reported by Meyers, rather than the direct attack on the basal ganglia. Acting upon these considerations, therefore, Browder (37) in 1947 devised a new operation which has since acquired the name of "internal capsulotomy" (FIG. 74). An incision is carried into the anterior portion of the lateral ventricle exposing the head of the caudate nucleus; the upper half of that structure is then removed, either by suction or a scoop, to expose the inner fibers of the anterior limb of the internal capsule; and the most anterior of these fibers are curved in a rainbow fashion from forward-aft to enter the capsule. With a blunt right-angled hook, the arm of the hook being 0.8 centimeter in length, section of the fibers of the internal capsule is begun at the rostral end of the capsule to a point approximately 1 centimeter anterior to the knee of the capsule. In 1948 Browder (38) reported that he had up to

that time performed this operation on 15 patients, in 9 of whom the disease was limited to one side. In 6 of these 9, tremor was abolished; in 1 patient it was absent for the most part, and in 2 patients it was temporarily abolished. Of the 6 patients who had bilateral symptoms before operation, 3 died as a result of the operation; the other 3 had the operation performed on one side only—these survived but were not greatly benefited. Two of the 15 patients have been observed for a period of 5 years since operation without recurrence; one is employed as a watchmaker.

All had been "quiet on this front" for about 10 years when, in 1952, a bomb was dropped in the camp by Cooper (61). While undertaking to perform a "pedunculotomy" (Walker's operation) for the relief of unilateral parkinsonism, he accidentally tore the anterior choroidal artery and in order to control the bleeding occluded this artery with a silver clip. Because of this complication he discontinued the operation at this point and returned the patient to the ward.

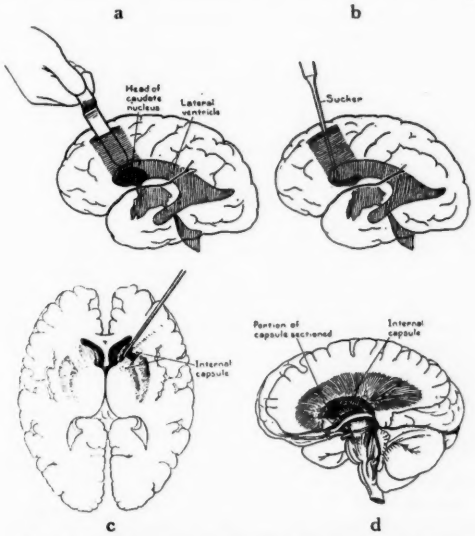

FIG. 74. Treatment of parkinsonism by "internal capsulotomy" as advocated in 1948 by Browder.

a, Lateral view indicating approximate site of cortical incision and approach to the ventricle.

b, Removal of part of the head of the caudate nucleus to expose the fibers of the anterior limb of the internal capsule.

c, Manner of sectioning the fibers of the internal capsule.

d, Indicating approximate amount of fibers to be sectioned.

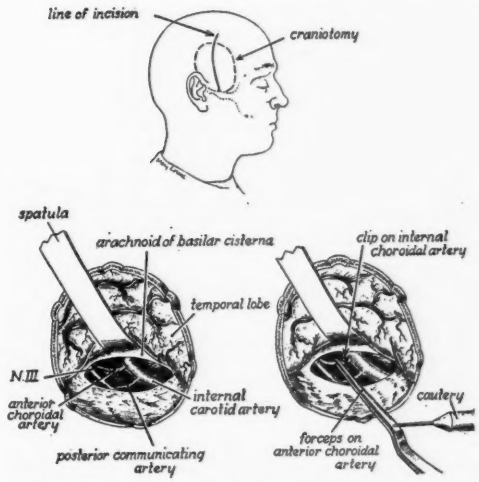

FIG. 75. Treatment of parkinsonism by ligation of the anterior choroidal artery as described by Cooper (1953).

When the patient recovered from the anesthesia, Cooper was astonished to find that the tremor had disappeared from the affected extremity and that there was no accompanying weakness in the extremity.

In 1953 Cooper (61) reported deliberate occlusion of this artery (FIG. 75) in 2 patients with alleviation of tremor and rigidity and without associated hemiparesis, hemihypesthesia, or hemianopsia.

Cooper's report created quite a sensation and his operation was soon being performed by other neurosurgeons (63). Their aggregate experience indicated that results of the operation were not uniformly predictable; in some instances there were disappointing failures to reduce the tremor and in other instances there were undesirable side effects such as hemiparesis, hemihypesthesia, and hemianopsia. It gradually became apparent that these variations in results were due to the fact that the area of the basal ganglia irrigated by the anterior choroidal artery was not the same in all patients, and this raised considerable skepticism as to the general feasibility of this procedure. However, in November, 1954 Cooper (63) reported the surgical occlusion of the anterior choroidal artery 40 times in 34 patients, that is, it was done bilaterally in 6 patients. In these cases resting tremor was "virtually abolished" in the extremities contralateral to the occluded artery in 70 per cent of the cases; in the

remainder the tremor was decreased. Motor power was not compromised. Rigidity and disabilities provoked by it were significantly decreased in every case of successful occlusion. The operative mortality was approximately 10 per cent.

Cooper's operation is intended to produce an infarct in the globus pallidus and, when successfully performed in patients with the usual arrangement of the anterior choroidal artery, there can be no doubt that such a lesion in this region favorably affects parkinsonian tremor without causing serious, undesirable side effects. It is only when anomalies in the areas irrigated by this artery are present that the results are otherwise. Unfortunately there can be no prescience of the distribution of this artery before operation.

Efforts are already being made by Cooper and by others to produce lesions in the globus pallidus by using techniques which are more precise than the production of infarcts through ligation of the anterior choroidal artery. It is yet too early to report on these current efforts, but they would appear to hold great promise.

Treatment of Mass Spasm Associated with Paraplegia

The problem of mass spasm secondary to paraplegia received attention from the time of Foerster (165), who in 1908 first performed a posterior rhizotomy for relief of spasticity resulting from disease of the corticospinal pathways.

In 1933 Munro (335) performed perhaps the first *anterior* rhizotomy for paraplegic spasm. He sectioned all the anterior roots bilaterally from about the tenth thoracic to the first sacral segment. Following World War II anterior rhizotomy was revived by Munro and was widely used in the armed services and veterans' hospitals for the relief of severe paraplegic spasm.

In 1917, just at the close of World War I, Riddoch (397) published a paper reaffirming the observations and opinions previously expressed by Romberg (399), Charcot (55), and Gowers (211), which has largely influenced all subsequent thought in respect to the mechanism and significance of mass spasms encountered in paraplegic patients.

Riddoch reported in great detail his observations upon 5 patients with verified transection of the spinal cord, 4 of whom lived for many months after their injury. Each of these 4 patients, after passing through an initial period of hyporeflexia, which Riddoch regarded as a state of "spinal shock," eventually developed mass spasms of the lower extremities which Riddoch believed to be the true state of chronic "*reflex*" activity in the human being following transection of the spinal cord. Although Riddoch very carefully avoided ascribing these "mass reflexes" to the "release" of the isolated segments of the cord from the influence of the brain, there is no doubt but that the general interpretation given Riddoch's observations was that these mass contractions were actually vestigial *intersegmental spinal reflexes* which had been reactivated by their release from the inhibitions imposed by the higher centers in the brain. They were thought to be analogous to the "righting reflex" seen in laboratory animals with transected spinal cords.

In 1946, just at the close of World War II, Scarff and Pool (417), on the basis of personal observations of hemiplegic patients, challenged this interpretation of the etiology and the significance of the involuntary mass spasm seen in paraplegics. They pointed out that the pattern of mass movements in man following transection of the spinal cord is neither constant nor predictable: of 12 of their patients with verified transection of the cord at middle and upper thoracic levels, 7 developed involuntary mass spasms, while 5 did not. No relationship could be established between the level of the transection and the occurrence or nonoccurrence of the spasm, nor any constant time relationship between transection of the cord and appearance of the spasm. Furthermore, 2 transections at approximately the same level would result in two widely different spasm patterns, while in no case observed by them did these patterns appear to constitute any fragment of a purposeful movement of the extremities or to resemble even remotely any vestigial spinal intersegmental reflex.

Because the mass spasms in the patients studied by them were neither constant nor predictable, Scarff and Pool expressed the opinion that these spasms were not *physiologic*, but *pathologic*, in nature and were in fact the result of repeated irritative stimuli arising from internal gliosis and external scars which had developed in and about the stump of the isolated segment of the cord. These irritative stimuli, in turn, acted upon spinal segments no longer under the control of the brain.

These authors re-explored 6 patients with previously verified transections of the cord; in each

instance they found marked gliosis within the stump and the stump densely bound to the dura with dense cicatrices; electrical stimulation of the cord showed a significantly lowered threshold to stimulation in the vicinity of the gliotic and adherent stump; clean surgical transection of the cord immediately caudal to the gliotic and adherent stump resulted in cessation of all mass spasms although the single segmental reflexes were not abolished. Detailed studies of the reflex activity in the lower extremities before and after these secondary surgical transections were reported (413, 418).

As a result of these various observations Scarff and Pool (417) suggested "an irritative mechanism" as an important etiologic factor in the development of massive spasms following transection of the cord in man. Constant and oft-repeated traction on the adherent stump of the distal segment or the irritative effect of gliosis within the stump, they felt, increased the irritability of this portion of the cord and lowered the threshold for afferent stimuli. Afferent impulses arising in this hyperexcitable zone are then transmitted to the more distal segments chiefly, though possibly not entirely, by the dorsal columns in antidromic direction. It was recognized by them that "release" of the cord from the influence of the brain probably played a primary role in *conditioning* the isolated segments for the development of spasms, but they believed that the actual occurrence of spasm in any given case of a transected cord was determined by factors operating upon or within the isolated segments chiefly at the site of the lesion, pathologic in character and irritative in nature. Acting on this hypothesis they excised gliotic and adherent stumps and divided the dorsal columns in 5 cases with temporary relief of spasms. When spasm returned, they re-explored and found that the fresh stump had, in its turn, become adherent to the dura.

In 1949 MacCarty and Kiefer (291) reported removal of a large portion of the thoracic, lumbar and sacral cords in an effort to eradicate a highly malignant glioma of the cord. They established the fact that removal of such extensive portions of the spinal cord was compatible with life but that certain unexpected physiological alterations in the body occur (292). The most striking effects of spinal cord removal for extensive injury were gynecomastia, hypoproteinemia, a decreased metabolic rate, and evidence of de-

FIG. 76. Egas Moniz.

masculinization. However, it was found that the bladder could contract and that intestinal function was only slightly altered. In 1954 MacCarty (290) reported extensive cordectomy in 4 patients suffering from severe mass spasm as a result of spinal injury. The segments removed were from the eleventh thoracic segment downward, including the conus and upper part of the cauda equina, and several more thoracic segments in the fourth case. The spasms were relieved; 2 of the patients established good automatic bladders and 1 patient, a fairly good automatic bladder; in another patient there was some continuing difficulty with management of the bladder at the time of publication.

Psychosurgery

Ferrier (161), Bianchi (29), and Goltz (210) all found changes of behavior in monkeys following ablation of the frontal lobes. Stimulated by these fundamental studies, Burckhardt (43), superintendent of a small Swiss mental hospital, was persuaded in 1891 to perform serial ablations of the brain in 6 patients which resulted in

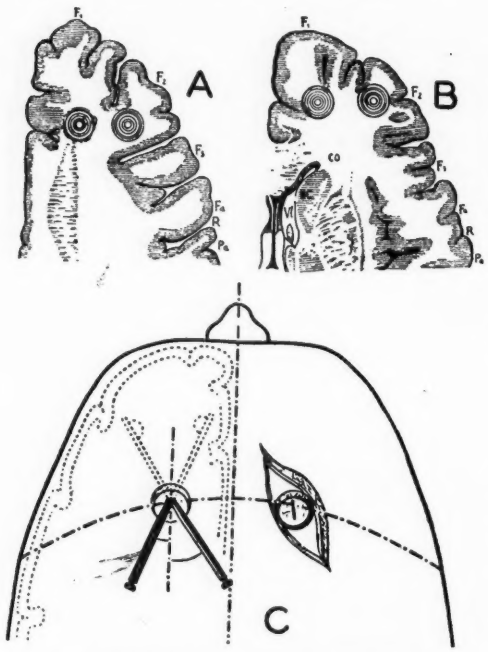

FIG. 77. Moniz and Lima's original technique of leucotomy (1936). A, The site of the upper cuts. B, The position of the lower cuts. C, The surgical incisions, trephine holes, and placement of the leukotome.

definite reduction in their restlessness and a general improvement in their mental condition. Burckhardt therefore should be regarded as the first psychosurgeon. Unfortunately he was far ahead of his time; his courageous pioneering efforts were not recognized and "psychosurgery" remained dormant for nearly half a century.

At the Second International Neurological Congress held in London in the summer of 1935, the function of the frontal lobes was one subject of discussion. Brickner (36) described in great detail the behavior of a patient whose frontal lobes had been radically removed by Dandy. This man, although less restrained, less inhibited, and less capable of complex synthesis, had little intellectual impairment. Jacobsen stated that chimpanzees in whom the prefrontal region had been removed bilaterally did not show tension, anxiety, or neurotic behavior when they made errors in conditioned responses. Preoperatively such frustration had caused these animals to pace about the cage or to cry whiningly.

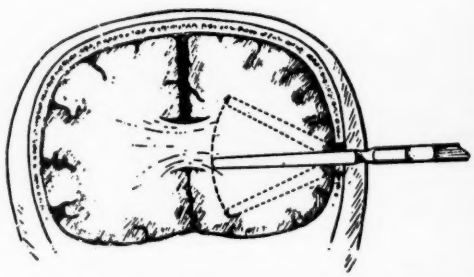

FIG. 78. Prefrontal lobotomy according to the "closed" method described by Freeman and Watts in 1942. For a time this was the standard technique generally employed in performing prefrontal lobotomy throughout the world.

Moniz (327) (FIG. 76), Professor of Neurology at Lisbon, Portugal, was very much impressed by these reports. It occurred to him that destruction of the frontal lobes would alter fixed neuronal patterns and thus change psychic patterns. Upon his return to Portugal he persuaded his neurosurgical colleague, Lima, to operate upon psychotic patients by making lesions in the frontal lobes (1936). Moniz devised an instrument for cutting a core of white matter, a cerebral leucotome consisting of a cannula through which passed a flexible wire obdurator which could be extruded from the side of the needle in the form of a loop. The instrument was inserted into the brain with the wire sheathed; at the desired depth the wire was pushed out and the cannula rotated, thus cutting a core of tissue about a centimeter in diameter. In performing lobotomy with this leucotome the surgeon usually makes six incisions near the centrum ovale of the prefrontal lobe (FIG. 77). Moniz reported that patients exhibiting anxiety, anguish, and worry were greatly relieved by operation; that cases of involutional melancholia, agitated depression, and other affective psychoses were practically cured; but that cases of schizophrenia were not benefited as greatly. This new procedure was readily accepted in Italy and in North and South America; it was not well received in France, Germany, or England.

The first leucotomy in the Western Hemisphere was performed by Mattos Pimenta (310) of São Paulo, Brazil. Later in the same year, 1936, Freeman and Watts (193) performed the first prefrontal lobotomy to be done on the North American continent, using a technique similar in most respects to that originally devised by

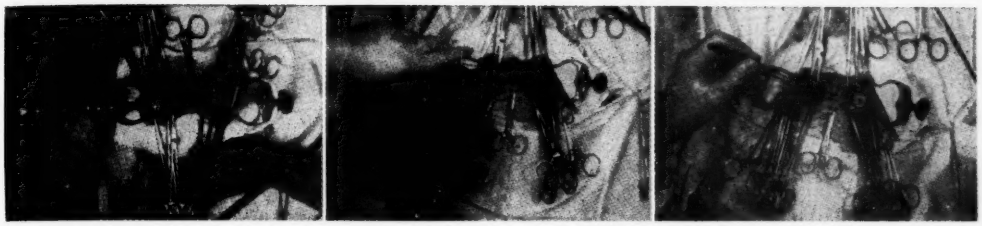

FIG. 79. Prefrontal lobotomy under direct vision, as first described by Lyerly in 1939. This "open" operation minimizes the danger of hemorrhage during the division of the white fibers of the brain, thus reducing both mortality and morbidity; it also permits a more thorough interruption of the association fibers in the plane selected for the leukotomy. The various steps in Lyerly's technique are described:

Left, Operative procedure; incisions have been made and buttons of bone are being cut and removed by the trephine.

Center, The dura has been opened; incision is made in the cortex; a lighted brain speculum has been inserted and the association fibers are being cut transversely.

Right, The dura has been closed and the buttons of bone are replaced in the wound.

Moniz. In 1942, however, they published a description of a new technique (194) which was to become the standard method for the "closed-type" of lobotomy from that date to the present. Through trephined openings placed near the junction of the frontal and temporal bones in the lateral extension of the coronal suture, a narrow, blunt-bladed "leucotome" was introduced into the brain and moved through an arc in the coronal plane (FIG. 78). A great number of patients were subsequently operated upon by this technique. However, even in experienced hands, the mortality accompanying this relatively simple procedure was unjustifiably high (in several series approximating 25%), and even in the successful cases a severe and prolonged postoperative morbidity was a frequent feature. This was true to such an extent that many days of deep stupor following the operation were even considered to be an essential part of the operation, permitting a "rebirth" of the personality from the amnesic state.

Lyerly (288), however, had a much more practical interpretation for both the postoperative mortality and the postoperative morbidity. He believed that these complications were due to the fact that by the closed operation blood vessels running in the depth of the brain were torn, which resulted in cortical hemorrhages of various size, and he set about to correct this serious fault which was inherent in all of the "blind" leucotomies. In 1939 he published a very important paper on lobotomy, which has not received the attention it is due, in which he described for the first time an "open" technique for performing prefrontal lobotomy under direct vision (FIG. 79). In introducing his procedure, Lyerly points out that the previous lobotomy techniques described by Moniz and Freeman and Watts are "more or less blind procedure[s] and it cannot be determined accurately how many of the fibers are cut or whether a blood vessel has been included in the section which may lead to serious hemorrhage. The operative procedure described in this paper overcomes these objections."

Lyerly's operative procedure is here described in his own words:

> The approach is made through a short transverse incision just back of the hairline on each side, centering over a point 3 cm. lateral to the midline and 3 cm. in front of the vertical line directly above the tragus of each ear. . . .
>
> A small button of bone is removed with a trephine on each side and this is saved in Ringer's solution during the operation to be replaced in the defect when the wound is closed [FIG. 79-a].
>
> The dura is opened by making a small flap exposing the cortex. The pial vessels are electrocoagulated . . . . an incision is made with a sharp knife. By means of a blunt dissector the incision is carried straight inward to the white matter of the prefrontal lobes.
>
> Then a two-bladed speculum is inserted [FIG. 79-b] so that the white fibers are seen while transverse incisions are made with a blunt knife or dissector carried from one side to the other as far as the cortex in all directions. Any important vessel can be felt with the light dissector, which can be carried around it and the vessel left intact, or if the vessel is injured or cut it can be controlled under direct vision by means of a silver clip, electrocoagulation or any other method that the surgeon may choose. The incision may be carried through the tip of the anterior horn of the lateral ventricle without any harm, but care should be taken not to injure the head of the caudate nucleus. As a rule it is preferred that the incision be carried just anterior to the tip of the anterior horn of the ven-

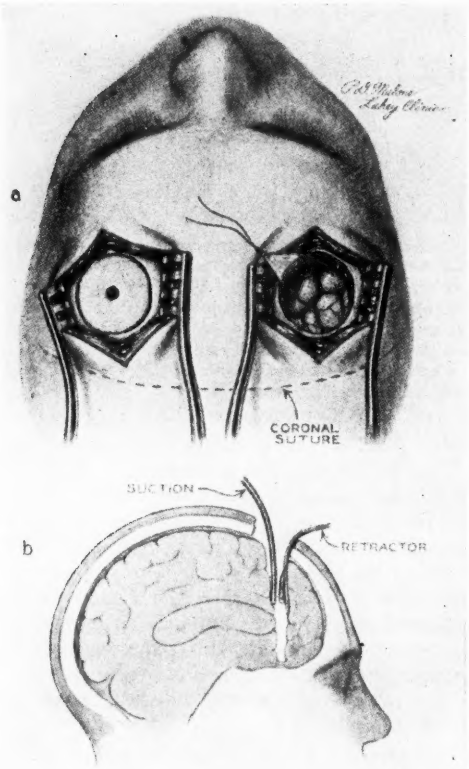

FIG. 80. Prefrontal lobotomy under direct vision as described by Poppen (1948). His technique differs only slightly from that originally described by Lyerly. Poppen is largely responsible for the rapidly increasing use of the "open" operation.

tricle. The same procedure is done on both prefrontal lobes.

After all the bleeding points have been controlled, the wound is closed by suturing the dural flap, replacing the button [FIG. 79-c] of bone, and suturing the galea and skin of the scalp.

Lyerly accompanied his original description of the open operation with a report of 2 cases in which the patient was successfully operated upon by this method. Subsequently, in 1944, he published a supplementary report (289), a statistical analysis, of 65 cases of bilateral prefrontal lobotomy performed by him on psychotic patients without a fatality, with 52.3 per cent of the patients being greatly benefited, 26.2 per cent moderately benefited, and 13.8 per cent slightly benefited in respect to their psychiatric illness.

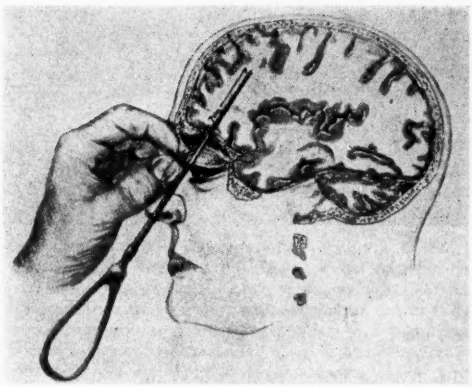

FIG. 81. Prefrontal lobotomy by the transorbital route. This was first performed by Fiamberti in 1937; subsequently by Fernandez-Moran (1946) and Freeman (1948). The above illustration was taken from an article by Freeman showing this operative technique.

In 1948 Poppen (380) described for the first time a technique for prefrontal lobotomy which he had used since 1943 in 470 patients; this was essentially the technique described by Lyerly except for the direction of the scalp incisions (FIG. 80). Poppen's large series of cases, with his low operative mortality, were undoubtedly responsible for the rapid and widespread acceptance of the "open" type of lobotomy as the standard neurosurgical technique today, largely superseding the earlier closed methods.

In 1937 Fiamberti (163) introduced transorbital psychosurgery. A cannula was introduced into the orbital cavity approximately 3 centimeters from the midline. If the needle encountered undue resistance at the vault of the orbit, it was lightly tapped with a hammer. The needle entered the orbital cavity, it was advanced into the frontal lobe, and 2 cubic centimeters of 95 per cent alcohol or 10 per cent formalin were introduced. Later Fiamberti (164) used a leucotome similar to that of Moniz and made a number of cuts in the white matter of the prefrontal lobe. In 1946 Fernandez-Moran (156) performed transorbital leucotomy in 21 debilitated psychotic patients and claimed results as satisfactory as those obtained with lobotomy.

Freeman (191,192) introduced the technique in the United States in 1948, except that he gave two electric shocks instead of anesthesia to render the patient unconscious; his technique was essentially that of Fiamberti (FIG. 81).

In an effort to produce lesions which were consistently reproducible and which would give a wider range of more selective functional results, a number of investigators planned a project to carry out localized frontal lobe ablations in psychotic patients. In 1949 a group of investigators (315)—the Columbia-Greystone associates—carried out ablations of a number of special areas of the cortex in a series of psychotic patients in the hope of finding a discrete area or areas of the brain, of which ablation would relieve psychiatric symptoms without producing the undesirable results attending the quantitatively greater isolation of the prefrontal lobes resulting from the standard lobotomy procedures. As a result of their studies they came to the conclusion that the surgical removal of segments of the frontal lobe which were presumed to conform to Brodmann's areas 9 and 10 produced these desired results. Pool (377,379) carried out the ablations for this group and gave the name "topectomy" to the operation (FIG. 82).

In 1949 Scoville (424) introduced "selective undercutting" of areas of cortex (FIG. 83) in lieu of the cortical ablations required in topectomy. He performed selective undercuttings in three general areas: (1) the lateral surface of the frontal cortex, corresponding roughly to Brodmann areas 9 and 10, (2) the inferior or orbital surface of the frontal lobe, and (3) the cingulate gyrus

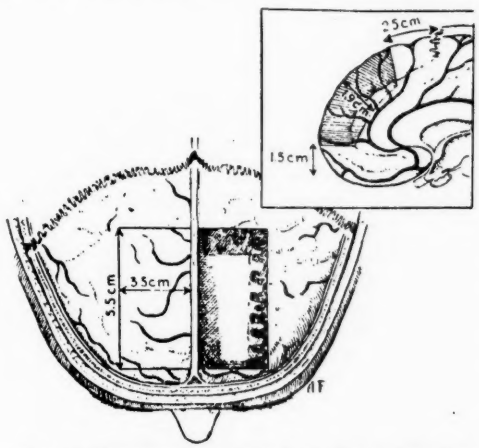

FIG. 82. Topectomy as described by Pool (1949). Topectomy was based on the premise that excision of areas 9 and 10 of Brodman would have *specific* favorable effects on psychotic behavior of patients with minimal disturbances of personality and intellect. Both the original premise and the operative technique have undergone some revisions.

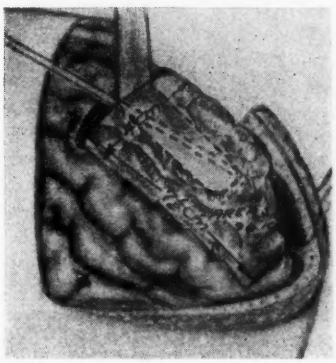

FIG. 83. Treatment of psychoses by "orbital undercutting" as described in 1948 by Scoville. His results were the same whether the undercutting was done on the lateral, medial, or inferior surfaces of the hemisphere. This has been taken to indicate that the *amount* of cortex isolated rather than the specific *area* was the important factor in the surgical treatment of psychoses.

and medial surface of the frontal lobe. It was Scoville's conclusion that the effect on psychoses of undercutting each of the three areas was essentially the same. The significance of this would appear to be that the *location* of the area in the brain isolated by operation is less important than the *amount* of brain thus isolated, in affecting psychotic behavior.

In 1948 Spiegel, Wycis, *et al.* (437, 438) reported the treatment of psychoses by small lesions made in the dorsomedial nucleus of the thalamus by means of a large Horsley-Clarke stereotaxic apparatus which they termed a "stereoencephalotome"; this apparatus allowed the exact placement of lesions in the thalamic nuclei. The patients were said to be relieved of anxiety, emotional tension, and allied symptoms.

In 1951, at the request of the American College of Surgeons, a symposium on the results obtained from the treatment of psychoses by each of the described methods was organized and presented in a brief but authoritative form. Through special courtesy of the editors of SURGERY, GYNECOLOGY AND OBSTETRICS this symposium was published *in toto* as a special section of the May, 1951 issue of that journal (421). Other more detailed studies of the psychiatric effects of the various operations have been published (196,214).

Studies in Cerebrovascular Circulation

Following closely upon the introduction of arteriography, the consequent greatly increased

interest in intracranial arteriovenous anomalies, and the growing attempts at direct surgical attack upon these conditions, came evidence that the basic groundwork of knowledge regarding the anatomy, the physiology, and the pathology of the cerebral circulation was woefully inadequate.

The neurosurgeons therefore have recently been devoting a great amount of time and effort to filling in these gaps in their knowledge, and within the past few years have brought forth a large number of new and fundamental observations on the cerebral circulation as it pertains to intracranial surgery. These have included anatomical studies of the intracranial vascular systems (23,395,466); of the establishment of collateral circulation following occlusion of the primary arteries of supply (344,470,476); of intracranial blood pressure levels and their relationship to pressures in the carotid arteries in the neck before ligation, after partial ligation, and after complete ligation (18,19,35,428,429,499), and also during peripheral hypotension temporarily induced by drugs (204,403,404,497); on the increase of intracranial pressure during angiography (456); on the effect of contrast media on the "blood-brain barrier" (24); on the complications of angiography (144); and on the roentgenographic and clinical results of occlusion of the major dural sinuses (254,395).

On the clinical and surgical sides, there have been statistical studies made of the behavior of intracranial aneurysms if left untreated (137, 219,220,340,349) and on the results of treatment by ligation of the carotid artery in the neck (31, 34,137,219,340,349,381,485).

Studies are currently being made both in the laboratory and in the operating room regarding the length of time various areas of the brain can tolerate complete occlusion of the principal artery supplying them or of the principal artery plus its chief source of collateral supply, as well as even total ischemia (279).

The effect of induced hypothermia in lengthening the period of tolerance to relative or absolute ischemia of brain tissues is also currently a subject of active investigation (280), and the fact has already been established that within certain limits reduction of the body temperature undoubtedly greatly prolongs the survival period of nervous tissue temporarily deprived of its blood supply. Such information is of immeasurable potential value in the development of techniques for radical extirpation of intracranial aneurysms and particularly of large arteriovenous anomalies of the brain.

One of the most valuable technical aids, not only to the actual surgery of blood vessel anomalies but to such studies as have just been outlined, is an ingenious arterial clamp devised by Selverstone[17] which permits precisely controlled occlusion of large vessels in the neck, quantitatively and temporally, in respect both to compression and to release of compression over a period of several days.

The studies in cerebrovascular circulation are increasing rapidly in number (18); they are already too numerous to catalogue in this report.[18]

Total Hypophysectomy in the Treatment of Malignant Disease

In 1936 Charbanier *et al.* (52), reported presumed total hypophysectomy for the treatment of severe diabetes, but unfortunately the question of whether total removal of the gland had been accomplished was never checked by autopsy. In the same year Elden (148) reported endocrinological findings in a 15 year old girl on whom Van Wagenen had attempted total hypophysectomy to ascertain the effect of that procedure on intractable epilepsy. In this case, however, subsequent autopsy revealed that 10 per cent of the normal gland had been left (149). On January 25, 1951, total hypophysectomy was performed in Naffziger's clinic for the treatment of a verified metastasizing melanoma and was reported in 1952 by Shimkin *et al.* (431). The second recorded hypophysectomy for the treatment of malignant disease was performed on July 6, 1951, by Olivecrona and was reported in 1952 (285). In the same year Perrault (372), in a discussion at a meeting of the Société Médicale les Hôpitaux de Paris held in February, 1952, is on record as saying that at his request LeBeau had performed a hypophysectomy on a patient suffering from malignancy on or about December 1, 1951, and this reference appeared in the printed literature of 1952. In 1953 Olivecrona (286) published a report of total hypophysec-

[17]An exhaustive search of the literature from 1940 to 1955 by the author has failed to disclose any recorded description of this instrument—except in the catalogue of Codman and Shurtliffe. This inventor should take pen in hand!

[18]The reader especially interested in this subject is referred to the excellent historical review of this entire problem in "A History of Neurological Surgery," edited by Walker (490), written in 1951. For contributions made since 1951, interested readers are referred to the issues of the "Journal of Neurosurgery" from 1951 to 1955.

tomy in 26 cases: in 12 for treatment of malignant tumor, in 3 for treatment of Cushing's syndrome, in 7 for malignant hypertension, and in 4 for treatment of diabetes mellitus. The most constant result of hypophysectomy on malignant tumors appeared to be relief of pain, which occurred in every patient operated upon; a majority of the patients also showed temporary arrest or remission of the growth of the neoplasm. The results of hypophysectomy on diabetic patients were variable and not decisive. Malignant hypertension did not respond favorably.

At the annual meeting of the Society of Neurological Surgeons held on April 24, 1955, Olivecrona (287,348) reported on results of total hypophysectomy in 50 patients, and at the same meeting Ray (394) reported his results of hypophysectomy in 70 patients. The results were almost identical in the two series, relief of pain being the outstanding effect of the operation. Both reporters described striking arrest of malignant growths and even temporary recession, but neither could report a cure. The results in cases of carcinoma of the breast were best in women who had not yet reached the menopause. The effect of hypophysectomy would therefore seem to be similar to castration. The value of hypophysectomy in other diseases such as diabetes and hypertension was not remarkable.

Use of Radioactive Isotopes in Location and Treatment of Brain Tumors

In 1946 Moore (328) injected sodium fluorescein into patients with gastric carcinoma with the thought that when the tumor was exposed at laparotomy and viewed under ultraviolet light it might accentuate the difference between normal and carcinomatous tissue. Early in 1947 (331) the same procedure was carried out in patients operated upon for brain tumor. The differentiation was found to be much greater in brain tumors; almost invariably the tumor was fluorescent. Dural or cortical tumors could be fluoresced directly with a specially adapted mercury vapor lamp. In cases of subcortical tumors, needle biopsies taken through small openings in the exposed dura could be examined for fluorescence under the ultraviolet light.

In 1947 *radioactive* di-iodofluorescein (DIF) was developed by Boyack (33), and later a more pure product was developed by Tabern (469). After radioactive di-iodofluorescein is injected intravenously gamma activity over the head can

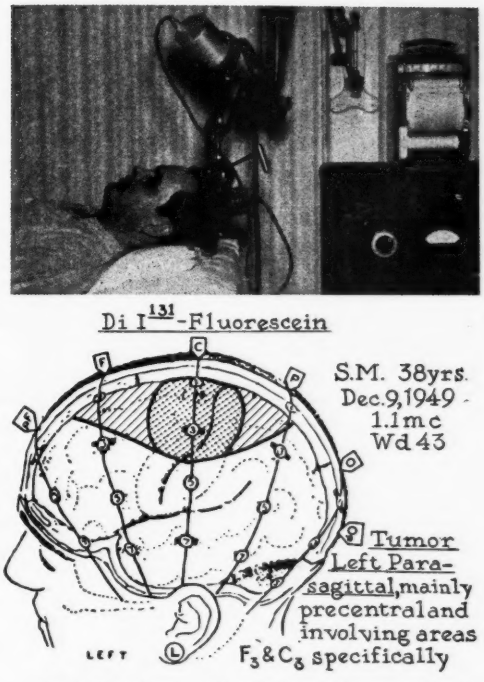

FIG. 84. Localization of brain tumors by means of radioactive isotopes was first developed in 1947 by Moore, Peyton, and French.

In 1954 Davis and Craigmile reported results of "isotope encephalography" in a series of 1,251 patients.

The illustrations above explain their technique.

be measured by a Geiger counter; the first such count (330) was made in September, 1947 by Moore, Peyton, Hunter, and French. In 1949 Moore, Hunter, and Hubbard (329) reported an analysis of 77 cases of brain tumor studied in this manner by them, and in 1952 Peyton, Moore, French, and Chou (374) reported that they had been able to localize accurately by this method alone 70 per cent of the intracranial tumors studied by them, and if the clinical data were utilized in conjunction with the radioactive isotope examinations correct localizations could be made up to 94 per cent. In 1951 Ashkenazy, Davis, and Martin (10) reported studies carried out in Davis's clinic in which they reported the use of radioactive di-iodofluorescein for the localization of intracranial lesions in 340 tumor suspect cases, giving a detailed description of the techniques and a statistical evaluation of the results (FIG. 84). Among the 340 cases in which

this method was used for localization of intracranial tumors there were only 17 errors made, making the method 95 per cent accurate in their hands.

In 1954 Davis and Craigmile (141) reported the results of "isotope encephalographic studies" in a total of 1,251 patients. In this group, 200 tracings had been made upon patients in whom an intracranial tumor was subsequently verified microscopically, 193 at operation and 7 at autopsy. In the individuals with primary intracranial tumors the test resulted in accurate localization of the verified lesion in 61.6 per cent of the patients examined. In 21 patients with metastatic intracranial tumors the test indicated the presence of an organic lesion in 68 per cent of the cases and precise localization of a solitary nodule in 47.6 per cent.

In 1952 Sweet and David suggested the possible use of neutron-capturing isotopes such as boron^{10} in the treatment of intracranial tumors. Chemical analyses in 58 cases after intravenous injection of the boron^{10} showed that this substance concentrates in many rapidly growing brain tumors to more than three times the extent that it does in normal brains. The technique for utilizing this property to treat brain tumors was described by the authors. The full potentialities of the technique await further development and evaluation.

Ultrasonics in the Localization and Treatment of Brain Tumors

High frequency sound waves when driven through tissues are believed to travel at a rate proportional to the tissue density and the tissue elasticity. These sound waves are reflected by surfaces in which a change of density or elasticity, known as an interface occurs; here "echoes" are produced. Depending upon the texture and thickness of the tissue through which the waves travel, the time interval before reception of the echo varies. With these known data it has been postulated that by measuring this time interval when ultrasonic pulses are sent through normal brain tissue the presence of an underlying subcortical neoplasm might be ascertained.

The first problem in the application of ultrasonics to the *diagnosis* of cerebral neoplasms centers about whether the texture of cerebral neoplasms varies sufficiently from normal tissue to be differentiated by ultrasonic vibration. The second problem is whether one can, by this method, establish with reasonable accuracy the presence of a subcortical neoplasm. The third problem is to ascertain whether pulsed ultrasonic vibrations of the proposed frequencies produce damage to normal cerebral tissues. These questions were first posed by French, Wild, and Neal (198) in the introduction to a paper which they published in 1951. As a result of their experiments, carried out in the laboratory on fresh normal brain tissue and fresh tumor tissue, the following conclusions were reached: (1) pulsed ultrasonic vibrations can be sent through normal and neoplastic cerebral tissues; (2) the texture of the neoplastic cerebral tissues is such that ultrasonic response is approximately twice that of normal cerebral tissues; (3) subcortical cerebral neoplasms have been located in postmortem material by this method of investigation; (4) pulsed ultrasonic vibrations of this frequency did not produce demonstrable change in the cerebral hemispheres of experimental animals.

The opinion that ultrasonic rays could be used in making focal *destructive lesions* in human beings or in making electively localized lesions in the central nervous system in laboratory animals which are quantitatively reproduceable from one animal to another was expressed by Mosberg and Tucker (333), and by Fry (200,201). Such discrete lesions, they showed, could be made in the depth of the brain without disturbing intervening tissue and without the destruction of blood vessels.

Although the term "ultra sound" is applied to all sounds with a frequency (pitch) which is above the range of human audibility, that is, 15,000 to 20,000 cycles per second, the frequencies employed by these authors were very much greater, in the neighborhood of 1,000,000 cycles per second. These sounds are of such high intensity that they must be transmitted through a liquid medium. They are generated from a quartz crystal excited electrically to vibrate in resonance. They are then focused upon the desired point by means of a polystyrene lens placed in front of the vibrating crystal. By means of this lens focused beams of sound as small as 1.5 millimeters in diameter are readily attained. Transmission of the sound from the lens to the tissue is accomplished through physiological saline solution. This liquid must be de-gassed by boiling to prevent the formation of bubbles which would interfere with the transmission of

the ultrasonic waves at the high intensities used in these experiments. The bone overlying the region of the central nervous system through which the sound is to enter must be removed in order to eliminate absorption by the bone which would cause local heating, and also to insure a sharply focused ultrasonic beam in the nervous tissue.

A battery of four ultrasonic projectors (Fig. 85) which are focused upon a single point, and which are integrated with a stereotaxic base for holding and accurately positioning the subject's head has been constructed by these workers. A series of laboratory animals has been radiated. Utilizing this precision equipment, discrete destructive lesions a few millimeters in diameter have been placed precisely in designated areas deep in the brains of the animals, as confirmed by postmortem study by these workers.

Ultrasonic surgery would appear to represent the ultimate in surgery. It goes one step beyond stereotaxic surgery in refinement in that it permits the precise placement of discrete lesions at chosen points within the depth of the brain without leaving even the track of a needle or electrode in the intervening tissue. It undoubtedly will open up, even more widely than at present, new fields for physiologic research.

FIG. 85. "Ultrasonic surgery" (1955).

The ultimate in neurosurgical techniques is the use of "ultrasound" to produce surgical lesions deep in the brain without leaving even the tract of a needle or an electrode in the overlying tissues.

The above photograph shows a close-up view of a "multibeam irradiator" set up to make a lesion in the depths of a monkey's brain which can be seen exposed at the bottom of the field through an opening in the metallic shield.

The principles involved in the application of ultrasonics to neurosurgery have been studied by Mosberg, Tucker, and Fry. The instrument above pictured was built under the supervision of Fry.

PART III. NEUROSURGERY, 1955

THE NEUROSURGICAL TEAM

In 1905 there was *one* dedicated neurosurgeon in the United States, Harvey Cushing; in 1955 there are more than 400 certified neurosurgeons.

In 1905 the period of training for neurosurgery was a brief apprenticeship of several months; today the minimum requirement for certification as a neurosurgeon is 4 years of special training in an accredited neurosurgical hospital, with at least 2 years of practice limited entirely to this field.

In 1905 there were no neurosurgical societies or associations; today there are 5 national neurosurgical societies in the United States as well as numerous local and sectional societies; there are national neurosurgical societies in Great Britain, France, Scandinavia, the countries of the Iberian Peninsula, and in many of the countries of South America; there is a South American Congress of Neurological Surgeons; and there is now forming an International Neurosurgical Congress.

In 1905 the neurosurgeon was a rugged individualist working alone and often the object of curiosity among his fellow surgeons; today the neurosurgeon is the captain of a *team* comprised of a neuroanatomist, a neurophysiologist, a neuropathologist, a neurochemist, a neurophysicist, an electronic engineer, a specialist in isotopes, a mechanical and electrical engineer, a neurologist, and, last but not least, an anesthetist who must be familiar with induced hypotensions and induced hypothermias.

In 1905 the neurosurgical operating room contained an ordinary surgical table plus an electrical stimulator; today the neurosurgical operating room resembles the control room of a "spaceship," with myriad technical adjuncts.

In 1905 the immediate objective was the mechanical opening and closing of the brain case; today the avowed objective is the seat of consciousness of the human brain.

Today, as in 1905, Neurosurgery is still irresistibly "on the march"; where that march will lead is certainly beyond our present horizons.

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ABSTRACTS OF CURRENT LITERATURE

SURGERY OF THE HEAD AND NECK

HEAD

The Surgical Treatment of Benign Masseteric Hypertrophy. FRANK MASTERS, NICHOLAS GEORGIADE, and KENNETH PICKRELL. *Plastic & Reconstr. Surg.*, 1955, 15: 215.

SINCE 1951, six patients with an ill-defined tumor mass of the parotid region have been admitted to Duke Hospital, Durham, North Carolina, for treatment with a referring diagnosis varying from mixed tumor of the parotid gland to lymphangioma of the face. The diagnosis of benign hypertrophy of the masseter muscle was made and in this article the authors outline a method of treatment.

Benign hypertrophy of the masseter muscle is an unusual condition causing a unilateral or bilateral prominence of the side of the face. The diagnosis is frequently unsuspected because of the lesion's rarity. The diagnosis can be readily established by palpation, particularly with the teeth clenched.

The authors describe two techniques for the correction of this deformity. It is their opinion that the method of excision suggested by Adams is the preferable one because the danger of injury to the facial nerve and Stenson's duct is minimized. This approach also allows for the resection of a protruding mandibular spine.

The surgical treatment of benign hypertrophy of the masseter involves the resection of the hypertrophied musculature, as well as any abnormal bony spur formation at the angle of the mandible. Through a curved incision around the angle of the mandible, the parotid fascia is exposed and divided just below the free margin of the mandible. The tail of the parotid is retracted to expose the masseter muscle, and the mandibular and buccal branches of the facial nerve are identified, dissected free, and retracted to protect them from damage. The central two-thirds of the insertion are then freed from the inferior border of the angle of the mandible and the associated bony spur.

With the masseter retracted, a resection of the hypertrophied muscle tissue is carried out on its medial surface. When the muscle is reduced to normal thickness, an incision is made in the mandibular periosteum and the underlying bony spur is removed, either with a small chisel or a rongeur.

The authors present preoperative and postoperative views of some of their cases showing excellent results from this form of treatment. They emphasize that the operative technique described by William Milton Adams is preferred because it minimizes injury to the facial nerve and allows an adequate resection of any bony prominence at the angle of the mandible. —*F. W. Pirruccello, M.D.*

The Evaluation of the Physiologic Result from Submandibular-Notch Ostectomy, Condylotomy Operation for Prognathism. ARTHUR E. SMITH and MARSH ROBINSON. *Plastic & Reconstr. Surg.*, 1955, 15: 196.

THE AUTHORS state that a great many surgical techniques are described in the literature for the correction and reconstruction of the prognathic mandible. The very number shows, in their opinion, that in the past no single operation has proved entirely satisfactory. The various types of procedures that have been performed are presented in outline form with an excellent bibliography.

In preparing the patient for the operation of submandibular-notch ostectomy with sliding condylotomy, the authors feel that success will depend directly on the preoperative preparation. This includes the determination of the angle and extent of the ostectomy and condylotomy. All possible means of study should be used. Roentgen examination should include cephalometric measurements. Photographs and a face mask should be made. Accurate plaster models of the dental arches are mounted on an articulator with a movable mandibular unit. The postoperative centric mandibular relation to the maxilla is one which will establish the best intermaxillary reaction and occlusion. If orthodontic treatment is planned, part or all may be advisable before surgery. In most cases orthodontists advise that orthodontic treatment should follow surgery. A metal pattern is constructed in reference to the eye-ear plane to indicate the amount and direction of the ostectomy to be performed. The authors carry out their procedure under local nerve block anesthesia.

An incision is made in the preauricular area anterior to the ear, extending down along the anterior inner margin of the ear. The incision is ended approximately 0.5 cm. behind the lobule. The skin flap is elevated by sharp dissection to expose the region lateral to the mandibular notch adequately. That portion of the ascending ramus in the region of the mandibular notch between the coronoid process and the neck of the condyle is exposed. Division of the bone is made with a special, spiral, three-bladed bone burr

under a constant stream of normal saline solution. The template is placed on the bone and the outline marked with a scriber or burr. The first cut made is the anterior vertical cut, starting as far forward on the coronoid process as is necessary for the case at hand. The cut is carried vertically downward, not over 8 mm., and parallel with the anterior border of the template. The horizontal and posterior vertical cuts are then made. This completes the submandibular-notch ostectomy. The thin piece of bone is removed from the wound. At this point, two small drill holes are made, one through the proposed anteroinferior angle of the proximal fragment and the other in the ramus below the anterior vertical cut. An .018 stainless steel wire is looped between the two holes. The horizontal cut is then continued posteriorly to effect a condylotomy. Immediately on completion of this cut the muscles pull the mandible posteriorly, sliding on this ostectomy. The procedure is repeated on the opposite side. After both sides have received the submandibular-notch ostectomy, sliding condylotomy, the mandible is fixed with intermaxillary wires in the new position. These wires are removed in 6 or 7 weeks.

To date, 65 patients have had their mandibular prognathism corrected by this new technique. The authors present abbreviated case reports to illustrate long term follow-up. Three case reports are presented in detail. There is a series of excellent photographs and diagrams to show the exact technique that the authors use.

Arguments in favor of this new location of ostectomy are as follows: (1) there is no sacrifice of teeth, (2) there is no sacrifice of useful bone, (3) large nerves and blood vessels are not contained in the bone removed, (4) muscles of the floor of the mouth are not disturbed, (5) ligaments of the temporomandibular joint are not involved, (6) the site of ostectomy is not disturbed by the forces of the muscles of mastication, (7) the tongue space is not diminished, and (8) condylar function is not disturbed. In addition, the authors feel that location of the osteotomy produces a more physiologic result because the muscle forces do not cause derangement at the osteotomy site. Further, the procedure more nearly corrects the deformity. They state that the fault in these cases is in the rami and gonial angles. Some of the other procedures that have been performed to remove sections of bone from the body do not actually change the faulty lengths or angle of the rami.

The open procedure has advantages over the closed method because the area is exposed and corrected under direct observation. It also relieves the surgeon of the fear of cutting vessels or branches of the facial nerve, or of creating a parotid fistula.

In summary, it is stated that only through a long term follow-up of patients can a true evaluation of a particular surgical procedure be made. In order to evaluate their new method, the authors re-examined 65 patients whose mandibular prognathism was corrected by this operation between the years 1940 and 1954. In their opinion, the operation has been successful by all objective tests.

This article gives step-by-step detail of the operative procedure. It contains an excellent bibliography of the procedures that have been done in the past. It is recommended reading for those who are interested in this phase of maxillofacial reconstruction.

—F. W. Pirruccello, M.D.

EYE

Corneal Infections After Cortisone Therapy. YUKIHIKO MITSUI and JUN HANABUSA. *Brit. J. Ophth.*, 1955, 39: 244.

THE AUTHORS report 4 cases of fungus keratitis and one of Pseudomonas aeruginosa hypopyon keratitis that followed the topical use of cortisone or hydrocortisone for a week or longer. In one case a spore was recovered from scraping the cornea, which on culture was identified as the Candida albicans. In 2 cases the corneal scraping yielded the Aspergillus fumigatus, and in the fourth case the Penicillium spinulosum was found. The over-all incidence of fungus keratitis among cases given topical cortisone therapy was about 0.3 per cent. In 63 cases in which topical treatment with cortisone had continued for more than 3 weeks, conjunctival scrapings yielded various fungi in 67 per cent (42), while in a similar control group fungi were recovered in only 18 per cent. In 18 cases in which no fungus was present, hydrocortisone ointment was prescribed every 3 hours for 3 weeks, at the end of which period fungi were obtained in half of the cases. A Japanese antibiotic, trichomycin, which was found effective against fungi, was used in an ointment in 0.05 per cent concentration in 2 cases of fungus keratitis with a favorable response.

—James E. Lebensohn, M.D.

Chorioretinal Burns Produced by Atomic Flash. VICTOR A. BYRNES, D. V. L. BROWN, H. W. ROSE, and PAUL A. CIBIS. *Arch. Ophth.*, Chic., 1955, 53: 351.

THIS REPORT is the result of a large scale study of the effects of radiant energy released at the detonation of an atomic bomb in the form of infrared and visible light which produces chorioretinal burns. These burns are similar to the macula burns in eclipse blindness. However, an eclipse burn occurs through a very small pupil under an appreciable period of time, but in the atomic burn the energy is delivered almost instantaneously generally through a dilated pupil, particularly if the explosion occurs at night. The rapidity with which the energy is delivered does not permit vascular dissipation of the heat.

The material for the study was obtained from findings on 700 rabbits exposed during six atomic detonations in Nevada in 1953.

The physical factors concerned were considered in much detail and led to the prediction that ocular lesions could be produced considerably further away from an atomic explosion than any other damage to human beings.

Animal experiments show that the danger to the retina actually exists beyond previously estimated distances and a comparison is established for estimating the threshold distances for human eye lesions.

On microscopic studies, it seemed apparent that the pigment of the retinal epithelium and choroid is the principal site of absorption of the energy from atomic flash which produces intraocular lesions. These lesions

are characterized by a coagulation necrosis, accompanied by central major tissue destruction involving these same pigmented layers. Histologically, the gray retinal tissue, as seen with the ophthalmoscope, had a well preserved architecture. The gray color was interpreted to be the result of direct heat coagulation of the tissue and also the result of delayed autolysis.

Potential danger to the retina beyond previously estimated distances, that is, up to 36 miles in the daytime and up to 40 miles at night, is evaluated on the basis of a 20 KT bomb. The chorioretinal burns produced would be particularly important to the ophthalmologist in evaluating various phases of civil defense. Certain facts were emphasized by the authors. A large part of the energy is delivered so rapidly that blinking and pupillary constriction have limited protective value. As indicated above, the danger is greater at night for a greater distance. The darker the pigmentation of the retina the more susceptible it is to being burned. Visual defects will be severe if either the macula or nerve head are involved.

Future therapeutic possibilities were considered for small intraocular lesions and it was indicated that the first steps toward the development of the technique were being undertaken.

—*Andreas V. Mortensen, M.D.*

Experimental Approach to the Pathogenesis of Retrolental Fibroplasia; The Influence of the Developmental Maturity on Oxygen-Induced Changes in the Mouse Eye. LARS J. GYLLENSTEN and BO E. HELLSTRÖM. *Am. J. Ophth.*, 1955, 39: 475.

THE AUTHORS describe the experimental approach to the pathogenesis of retrolental fibroplasia.

It is known that high environmental oxygen plays an important role in the etiology of this condition, but other factors may also contribute to its development. It is also known that the incidence of this disease is higher in premature infants of the lower weight groups. Present experiments seem to provide further evidence of the pathogenetic relationship of the oxygen-induced changes in the eyes of mice and of human beings, and that there is a positive correlation between the immaturity of the eye and the severity and frequency of the oxygen-induced changes.

For these reasons, the authors exposed newborn mice and mice 5 and 10 days of age, respectively, to 98 to 100 per cent oxygen for 5 days, transferred them to normal air, and prepared them for examination one to 10 days later.

The findings were as follows:

All groups of mice presented hemorrhages in the eye (mainly in the nerve fiber layer and in the vitreous body), irregular proliferations of the nerve fiber vessels with capillary tufts budding into the vitreous body, and irregularities of the retinal layers.

In newborn mice the retinal changes were concentrated in the neighborhood of the optic disc; in older mice the changes took place in the more peripheral parts of the retina.

In mice exposed to concentrated oxygen at an earlier age, the hemorrhages and the irregular vasoproliferation were more pronounced than in mice exposed to oxygen at an older age. Older animals presented more retinal irregularities and foldings than younger ones, and an increasing frequency of a characteristic retinal atrophy of the ganglionic layer, the inner layer, and the outer plexiform layer.

The authors conclude that although the oxygen-induced changes in mice, as described by themselves and by Ashton *et al.* and Platz *et al.*, showed great similarities to the early stages of human retrolental fibroplasia, there is no complete identity with regard to the histologic findings. The final cicatricial stage of retrolental fibroplasia seen in human cases has never been reproduced. For this reason caution must be observed in drawing conclusions from animal experiments relating to the mechanism producing the disease.

—*Joshua Zuckerman, M.D.*

The Treatment of Retinoblastoma by Radiation and Triethylenemelamine. ALGERNON B. REESE, GEORGE A. HYMAN, GEORGE R. MERRIAM, JR., ARNOLD W. FORREST, and MORTON M. KLIGERMAN. *Arch. Ophth.*, Chic., 1955, 53: 505.

THE AUTHORS discuss the treatment of retinoblastoma by a combination of radiation and triethylenemelamine.

Retinoblastoma had been treated previously by radiation alone, with special cones at a temporal and a nasal portal to deliver an adequate dose exclusively to the posterior, the less vulnerable, segment of the eye.

This treatment was employed to arrest the growth in the less involved eye in cases of bilateral tumors when the eye with the more advanced disease had been enucleated. Since 1936, this form of treatment had yielded useful or limited vision in 80 eyes (36.2%) of a series of 148; of these cases 43 had occurred in patients who had died and 26 in patients who could not be followed up.

Of the complications, late vitreous hemorrhage from retinal blood vessels damaged by irradiation was the gravest. To avoid this complication, the amount of radiation was reduced but the hemorrhages continued to occur.

When the use of radiation in combination with nitrogen mustard therapy was reported by Carl Kupfer, it occurred to the authors that the combination of x-ray treatment with a radiomimetic drug might enable them to make a considerable reduction in their x-ray dose. Triethylenemelamine (TEM) was chosen because, unlike nitrogen mustard, it can be given orally instead of intravenously. Moreover, Gillette and Bodenstein had reported that a close ally of TEM, namely methyl-bis (-chloroethyl) amine(MBA), had a specific effect on the proliferating retinal cells of amphibian embryos to the exclusion of other tissues.

There are two aspects to the treatment:

1. Radiation—220 kvp; 0.5 mm. of copper plus 1.0 mm. of aluminum filtration (H.V.L. 1.0 mm. copper); 20 ma.; 50 cm. T.-S. D.; a 2.5 cm. temporal port and a 2.0 cm. nasal port; 400 roentgens/air per treatment three times a week to alternate portals for a total of 2,400 roentgens/air to each within one month. The tumor dose is calculated to be approximately 3,400 roentgens (slightly more than half the dose when radiation was used alone).

2. Triethylenemelamine (TEM)—children under 12 months, 2.5 mgm. given orally; from 12 to 18

months (or under 20 lb., or 9,072 gm.), an initial dose of 3.0 mgm. if a preliminary survey, including complete blood count and platelet count, is satisfactory. An initial dose of 3.5 mgm. is used for older or larger children. The second and subsequent doses are given when the white cell count returns to at least 5,000 and the platelet count to 150,000, usually 6 to 8 weeks after the last treatment. Subsequent doses depend upon the depth of hematologic depression and the rate of fall.

The total course administered is approximately 15 mgm., in 5 divided doses; the first dose is given at the start and the second at the conclusion of the x-ray therapy.

Especially selected cases are now being treated with 2.0 mgm. given intra-arterially.

Because TEM therapy alone has not proved curative in the treatment of any neoplasm in the past, no matter how beneficial it appeared initially, TEM alone has not been assayed in the present series.

The authors conclude that on the basis of their experience with 34 eyes during 21 months starting with January, 1953, the treatment of retinoblastoma by a combination of radiation and triethylenemelamine is the best method to date for controlling this type of tumor.

In 19 eyes the condition showed satisfactory regression. Moreover, after additional therapy was instituted in 8 eyes which had manifested active growth after completion of treatment, the lesion regressed satisfactorily in 3. —*Joshua Zuckerman, M.D.*

NOSE AND SINUSES

The Flanged Acrylic Implant in Nasal Reconstruction. DERRICK DENCER. *Plastic & Reconstr. Surg.*, 1955, 15: 328.

AN ACCOUNT is given of the various materials which are available for reconstruction of the nasal bridge line. These are classified under the headings of (1) autografts, (2) homografts, (3) heterografts, and (4) foreign bodies. Autografts are comprised chiefly of bone and cartilage. These must be obtained from a donor area of the patient. Bone is difficult to mold; cartilage undergoes distortion in 40 per cent of the cases (Mowlem). Homografts of cartilage are unreliable and undergo distortion. Converse has used homografts of bone with promising results in an early follow-up period. Heterografts, such as bovine cartilage have given poor late results and their use should be discouraged.

To be successful, a foreign body tissue implant in the nose must contain the following properties:

1. Light weight.
2. Correct anatomic shape corresponding with the nasal cartilage so that it can take purchase on the bony points.
3. Rigidity, firmness, and ease of modeling.
4. Must be inert (according to Scales criterion): (a) inert to body fluids; (b) chemically inert; (c) excite no inflammatory or foreign body reaction; (d) noncarcinogenic; (e) nonallergenic; and (f) capable of sterilization.

The author has used an acrylic implant (methyl methacrylate) which consists of a bar conforming to the nasal bridge line and a wide, thin flange projecting below it. When introduced into human tissues, it has excited no inflammatory response. It does not absorb, extrude, and is inert and easily fashioned. It is designed to rest on the nasal bones and the anterior nasal spine, and the lower border rests on the crest of the maxilla and the anterior edge of the vomer, as shown in Figures 4, 5, and 6. The implant is inserted under general endotracheal anesthesia through an incision which separates the columella from the lip, and hinges it upwards. A pocket is created in the septum to accommodate the acrylic implant, removing most of the remaining septal cartilage first. The implant is trimmed to size and shape, great care being taken to remove all the resin dust, which is irritating in fine form. A plaster cast is used postoperatively for several days.

This method of restoring the contour of the nose was used in 38 cases over a period of 5 years. Only three failures were recorded during this period of time.

—*Carl Schiller, M.D.*

NECK

Hyperparathyroidism. JOHN N. HENRIE, ROSCOE M. NELSON and KENNETH B. CASTLETON. *Am. Surgeon*, 1955, 21: 403.

PRIMARY HYPERPARATHYROIDISM is nearly always due to parathyroid adenoma, rarely to carcinoma. The parathyroid glands are usually four in number, the lower pair developing with the thymus from the third branchial pouch, and the upper pair with the thyroid from the fourth branchial pouch.

The presenting symptoms of the patient with hyperparathyroidism may fall into one or more of three groups. Urinary tract changes probably lead to more correct diagnoses than any other group. Renal or ureteral stones occur, sometimes with polyuria and nocturia or with urinary tract infection. Skeletal system changes may predominate, with general decalcification and local cystic changes most common in the metacarpals, jaws, and ends of the long bones. Bone pain occurs early, skeletal deformities develop, and pathological fractures are common. Less likely to cause suspicion of hyperparathyroidism is the third symptom group. This is the group of symptoms due to the hypercalcemia itself and consists of vague muscle weakness, anorexia, and constipation.

Once suspected, the diagnosis of hyperparathyroidism is readily verified by laboratory and x-ray findings. Typically there is a high serum calcium and low serum phosphorus. The Sulkowitch test for urinary calcium is advocated as an excellent screening test for these cases. Since some calcium is combined with protein, a low or high total protein level may cause false low or high calcium values to be reported. If renal function is impaired, phosphorus retention may cause a normal phosphorus level despite hyperparathyroidism.

The treatment of hyperparathyroidism is surgical and the surgeon who first explores the area involved has the greatest opportunity to produce a cure. A bloodless field is essential so that the characteristic red-brown color of the glands is not obscured. In general, the more severe the symptoms, the larger the adenoma one expects to find.

Hypocalcemic tetany is the most common postoperative complication. Dihydrotachysterol is administered routinely, and calcium lactate is given orally. Parathormone may be needed the first few days. Oliguria is a constant postoperative finding, and its occurrence verifies the removal of a parathyroid adenoma. Four cases are reported. —*Stanley W. Tuell, M.D.*

The Vagal Body Tumor. SHELDON OSCAR BURMAN. *Ann. Surg.*, 1955, 141: 488.

THE VAGAL BODY lies within or upon the vagus nerve at the level of the ganglion nodosum or within the perineurium below the ganglion. Tumors of the vagal body may encroach upon many surrounding structures. The hypoglossal nerve is in close proximity, and the cerebral portion of the accessory nerve passes over the ganglion. Branches from the superior sympathetic cervical ganglion and the loop between the first and second cervical nerves communicate with it. The glossopharyngeal nerve and the auricular and tympanic branches of this nerve are in close relation. The jugular vein also has its origin at this point.

The vagal body consists of single or multiple lobules which are highly cellular and vascular. Each lobule consists of two types of cells; the predominate type being polyhedral with finely granular cytoplasm and large round or oval nuclei. The second type is a small cell with a deep-staining eccentric nucleus. Sinusoidal vessels are prominent. The vagal body is supplied by a sensory fiber from the glossopharyngeal nerve and possibly from the sympathetic chain as well. The vagal body is a member of the chemoreceptor system similar to the carotid body and the glomus jugulare.

It is differentiated from a paraganglia by the following criteria: (1) the innervation appears to be mainly sensory, (2) it has never been shown to secrete a pressor substance, and (3) it does not give a true chromaffin reaction.

This is the fifth case of a vagal body tumor in the world literature and the first of a widely metastasizing tumor. A detailed clinical description of the patient, a 38 year old white widow, is included. The patient has been followed up for 8 years, the diagnosis having been confirmed from the biopsy of a metastatic lesion in the skull. The patient shows evidence of involvement of the sixth, ninth, tenth, and twelfth cranial nerves. The most prominent clinical aspect of the vagal body tumor is the presence of a painless mass deep in the upper cervical area between the angle of the mandible and the mastoid process, displacing the lateral wall of the pharynx inward. The sensation of a lump in the throat with difficulty in swallowing may be present. It usually involves the last four cranial nerves although these symptoms may be late.

It must be differentiated from neurofibroma, branchial cleft cyst, lymphoma, tuberculous adenitis, or salivary gland tumor.

Four of the 5 reported cases of vagal body tumor have been in females and 4 of the 5 occurred in the fourth decade.

The majority of chemodectomas do not metastasize but are indolent, slow-growing lesions with local invasion.

The chemodectomas are completely radioresistant and surgical excision of the entire mass is the treatment of choice. —*John H. Davis, M.D.*

SURGERY OF THE THORAX

CHEST WALL AND BREAST

Plasma Cell Mastitis: a Review and Report of a Case. B. E. FERRARA. *Am. Surgeon*, 1955, 21: 376.

ONLY 76 CASES of plasma cell mastitis have been recorded in the literature since it was first recognized as a clinical entity 24 years ago. It is a rare inflammation of the female breast, grossly mimicking carcinoma, characterized by the presence of many plasma cells, proliferation of duct epithelium, and formation of giant cells.

Clinically, there are two phases to the disease. In the acute phase, there are varying degrees of the signs of inflammation. Local redness, tenderness, and swelling, a creamy nipple discharge, and even chills and fever may occur. This subsides in a few weeks or a month. The residual phase follows, with a firm, discrete mass in the breast, retraction of the nipple, chronic nipple discharge, and sometimes fixation of the mass to the chest wall. Enlargement of the axillary nodes completes the similarity to carcinoma. In general the disease involves parous women after lactation. The etiology is thought to be on a chemical rather than a bacterial basis.

The gross appearance on section is one of many thickened ducts filled with puriform material, extending through the involved gland. There may be much cellular debris resulting in an opaque yellowish mass. The proliferating cells of the duct epithelium eventually undergo fragmentation and multiple giant cells are seen microscopically, simulating a tuberculous process.

An accurate history may sometimes suggest the correct diagnosis, but in general biopsy is essential to differentiate the process from malignancy. After biopsy, local excision is usually adequate treatment, although simple mastectomy may be indicated in some instances. Opinions differ on whether plasma cell mastitis is a distinct disease entity. It may be only a variation of degree from other more commonly seen types of mastitis or even a variation of fat necrosis. A single case is reported. —*Stanley W. Tuell, M.D.*

TRACHEA, LUNGS, AND PLEURA

The Culmen: Anatomic Basis and Surgical Considerations (Le culmen: constitution anatomique et abord chirurgical). G. J. CORDIER and CABROL. *J. chir.*, Par., 1955, 71: 5.

THE AUTHORS believe that the lingula segment of the left upper lobe and the rest of the upper lobe form anatomic parts of the lung essentially related to the middle lobe and upper lobe on the right side. To the part of the left upper lobe other than the lingula, they apply the term "culmen." On the basis of anatomic studies they describe the standard distribution of the segmental bronchi, that is, an apicoposterior trunk and anterior bronchus well separated from the lingula. They also describe three major variations of their distribution:

1. A trifurcation of the upper lobe bronchus into the apicoposterior, and the anterior segments, and the lingula.
2. The anterior subsegment of the anterior segment supplied by a branch of the lingula bronchus.
3. The inferior part of the anterior segment supplied by a branch of the lingula bronchus.

They found a common origin of the lingula and anterior bronchi only once in 314 dissections.

The arterial supply to the culmen follows the bronchi by and large, although they are multiple. The authors point out the importance of the supply to the mediastinal aspect, and its inconstancy. In 13 per cent of their cases they found a branch of the latter passing to the lingula as well. Cross supply with the lingula would appear common. With the venous drainage the same problem appears even more commonly.

There is a detailed discussion of the anatomic variants. A complete discussion of the problems of excision of the culmen follows; it is profusely illustrated and requires only a modicum of French to understand. The scope is too detailed to abstract here.

The authors present some differences of approach to the usual ones and this article is worthy of study in the original by thoracic surgeons.

—*Roger H. L. Wilson, M.D.*

HEART AND PERICARDIUM

Cardiac Tamponade. J. L. FARRINGER, JR., and DUANE CARR. *Ann. Surg.*, 1955, 141: 437.

THE AUTHORS report 30 cases of cardiac tamponade collected between 1943 and 1953, with a mortality rate of 36.7 per cent. In the preceding 9 year period (1934 to 1943) a series of 35 cases had a mortality rate of 37.2 per cent.

Cardiac tamponade causes an increased venous pressure in both the systemic and pulmonic circulation, a reduced stroke volume and minute output of the heart, and a decreased coronary and cerebral blood flow. All these demand relief.

Classic signs include the presence of a wound, markedly narrow pulse pressure, dusky cyanosis, distant heart sounds, distended neck veins, and a not so rapid pulse. The absence of pulsations of the cardiac silhouette on fluoroscopy is a reliable diagnostic sign.

Immediate treatment is pericardial aspiration by the subxiphoid approach, the intravenous infusion of fluids, plasma, or blood, and oxygen given through the nose. Careful observation of the blood pressure and pulse is required and may indicate reaspiration or cardiorrhaphy.

Electrocardiograms will show changes compatible with acute pericarditis for days or weeks. Early ambulation is permitted. Patients are discharged after they have been afebrile for 72 hours, after the hemothorax is evacuated, and if the external wound is in satisfactory condition.

Although all patients in the early group (1934 to 1943) were treated by immediate thoracotomy, the

later group (1943 to 1953) were treated as follows: 8 patients by pericardial aspirations alone, 3 patients by pericardial aspirations followed by cardiorrhaphy, and 13 patients by operation only. In 6 patients, 5 of whom died, the penetrating wound of the heart was overlooked.

Aspiration produced ventricular fibrillation in one case and cardiac arrest in another. Delay in diagnosis or failure to make the correct diagnosis was largely responsible for 7 of the 11 deaths. In 23 patients who had prompt treatment, the mortality rate was 17.3 per cent. Patients treated by aspiration alone had no lower mortality but markedly less morbidity than those having major thoracotomy. Primary pericardial aspiration and supportive intravenous therapy are recommended for all patients with cardiac tamponade and open thoracotomy is reserved for those who manifest a continuing tendency to relapse.

—*S. Lloyd Teitelman, M.D.*

The Surgical Treatment of Chronic Pericardial Effusion and Cardiac Tamponade. EDGAR P. MANNIX, JR., and CLARENCE DENNIS. *J. Thorac. Surg.*, 1955, 29: 381.

IN RECENT YEARS the operative treatment of patients with inflammatory lesions of the pericardium has been generally limited in application, to those patients who were suffering from a constrictive type of pericarditis. Today the treatment of pericarditis with effusion is unusually carried out by the internist, who commonly employs repeated pericardicentesis to decompress the pericardial cavity. While this regimen is usually satisfactory, the authors believe that it may have the following disadvantages: (1) pericardicentesis has, on occasion, resulted in fatal hemorrhage; (2) cardiac tamponade usually is relieved only temporarily, and prolonged tamponade may result in serious myocardial, hepatic, and pulmonary damage; (3) the longer the infection in the pericardial cavity persists, the greater is the danger of progression to the constrictive phase of pericarditis.

Because of these disadvantages and because pericardiectomy is much more easily performed during the effusive rather than the constrictive stage of pericarditis, it is believed that the recent suggestion by Holman, of early pericardiectomy, has great merit and that the operation is indicated not only for patients with acute tuberculous pericarditis, as recommended by him, but also for some patients with idiopathic pericarditis.

The results were observed of elective pericardiectomy which was performed during the stage of effusive pericarditis in 4 patients, and the courses of 2 other patients were followed from the stage of effusion to eventual constrictive pericarditis, which required a technically more difficult operation. In the latter patients, symptoms and signs of cardiac tamponade persisted unnecessarily for several years while the stage of constriction developed. One patient had tuberculous pericarditis, but in 5 patients the etiology was undetermined. The ages of the patients ranged from 34 to 67 years. The predominating symptom in all patients was severe dyspnea. Some or all of the following signs of cardiac tamponade were present in each case before operation: hepatomegaly, ascites, low pulse pressure, low blood pressures, elevated venous pressure, prolonged circulation time, dependent edema, and low voltage electrocardiographic patterns. The apparent duration of the disease prior to operation averaged 17 months. Five of the 6 patients had moderate fevers and received streptomycin and PAS therapy for at least 2 weeks prior to operation.

Six case reports of patients undergoing pericardiectomy are presented. In 4 of these, the operation was performed during the stage of effusion and in 2 during the stage of constriction. All patients had signs of cardiac tamponade during the stage of effusion and at the time of operation. Pericardiectomy brought prompt relief of cardiac tamponade and striking general improvement in all patients. One patient died unexpectedly 2 years after operation of undetermined causes after previously feeling well.

The authors believe that the surgical treatment of patients with pericarditis should be formulated on the basis of a knowledge of the pathogenesis of the disease. Progression of pericarditis with effusion to the stage of constriction is not uncommon. Rigid distinctions between the stage of adhesive pericarditis (accretio cordis) and constrictive pericarditis (concretio cordis) may be misleading, according to Moschcowitz who believes that adhesive pericarditis is simply the earliest stage of constriction.

If these concepts concerning the pathogenesis are valid, it would appear these are additional reasons why pericardiectomy should be performed in selected cases much sooner in the course of the disease, ideally during the stage of effusion. The early operation is recommended in both the tuberculous and idiopathic types of pericarditis whenever a prompt remission in constitutional symptoms and disappearance of the fluid do not occur with conservative therapy. Any patient with an appreciably thickened parietal pericardium in the presence of effusion should likewise have pericardiectomy. The operation has not been performed during the effusive stage of rheumatic pericarditis for fear of the presence of active carditis.

Resection of the pericardium is preferred rather than pericardiostomy, for the following reasons: (1) it provides better drainage of the pericardial fluid (it is well known that the pericardial sac, because of its configuration, is not anatomically suited for complete, dependent drainage); (2) the problem of sealing over of the pericardial stoma is eliminated; (3) pericardiectomy removes a part or all of the focus of infection; (4) complete visualization of the visceral pericardium is obtained and resection of this layer can then be performed if such action seems appropriate to the surgeon.

—*Alan L. Dorian, M.D.*

Limitations of Cardiac Surgery Under Hypothermia; Experimental Study (Les possibilités actuelles de la chirurgie cardiaque sous hypothermie; travail expérimental). CH. DUBOST and CLAUDE D'ALLAINES. *J. chir.*, Par., 1955, 71: 285.

EXPERIENCE based on 68 cardiac operations on dogs during hypothermia is given. Both vena cavas may be clamped for 8 minutes at a body temperature of 29 degrees C. and for 12 to 15 minutes at 25 degrees C. Hypothermia below 25 degrees C. causes serious cardiac complications. The normal dog's brain tol-

erates circulatory arrest for 15 minutes at 28 degrees C. and for 20 minutes at 25 degrees C. There is increased risk to both heart and brain when there is pre-existing chromic hypoxia. Ventriculotomy is more apt to induce ventricular fibrillation than is auriculotomy.

One may stop the circulation for 30 minutes in a dog by lowering the temperature to 15 degrees C. without fatality. However, the risk of this degree of hypothermia is too great for the application to human beings.

At hypothermia of 25 degrees one may stop the circulation for 45 minutes provided that the coronary and cerebral circulation are perfused with oxygenated and heparinized blood. The authors are at present studying techniques to accomplish this in the dog.

During hypothermia blood potassium and chloride levels rise. Sodium and phorphorus levels remain unchanged. Hematocrit usually rises, and blood viscosity increases. The coagulability of the blood remains the same. The blood *pH* is lowered and carbon dioxide combining power of the blood is increased. Hypercapnic acidosis develops, which is toxic to the myocardium and causes disturbances of the rhythm.

Ventricular fibrillation may occur if air is allowed to enter the left heart, and extreme care must be taken to avoid this occurrence during open cardiac surgery. Coronary air embolus is invariably fatal.

The authors used hexamethonium, chloropromazine and hydergine in conjunction with hypothermia. In general, the hypotensive effect of drugs is enhanced by hypothermia, and the use of these drugs is risky.

Digitalis and sparteine are of no use during hypothermia, and sparteine occasionally causes ventricular tachycardia. Adrenalin causes fibrillation of the anoxic heart and hence is contraindicated during hypothermia. —*Frederick W. Preston, M.D.*

Coarctation of the Aorta with Special Reference to the First Year of Life. WILLIAM T. MUSTARD, RICHARD D. ROWE, JOHN D. KEITH, and ANNA SIREK. *Ann. Surg.*, 1955, 141: 429.

THE AUTHORS reviewed data on 90 infants and children with coarctation of the aorta seen during the past 10 years. These were divided into preductal and postductal groups, and into age groups of under and over one year.

Postductal coarctation under one year comprised one-sixth of the total, with a mortality of 60 per cent. Patients with preductal types under one year of age rarely survived the first few months of life, and constituted a special problem. Two-thirds of all patients with coarctation of the aorta present signs or symptoms in infancy, and most of them do not survive the first year of life.

Postductal coarctation is usually suspected in infants with heart murmur, dyspnea, absent femoral pulsations coupled with blood pressure higher in the arm than in the leg. The heart is usually enlarged, and the electrocardiogram may show left ventricular hypertrophy. Aortograms demonstrate narrowing and may show a patent ductus.

Preductal coarctation has similar presenting signs. Cyanosis usually indicates an associated defect. Angiocardiography is preferable in the presence of cyanosis, and aortography in its absence.

A left posterolateral incision in the fourth and fifth interspaces is employed. The coarcted area is resected and the aorta is approximated. There were 12 postductal patients more than a year old with one death and 4 under one year of age with no deaths. In the preductal cases there were 9 operations with 5 deaths, usually due to serious associated defects. Babies who survived were relieved of their failure, and their blood pressures returned to normal.

In view of the high mortality (89 per cent) in preductal coarctation, early surgical relief is indicated. Potentially fatal postductal cases should also be operated upon early. Preserved grafts are contraindicated as they will probably neither grow with the aorta nor withstand the trauma of a lifetime.

—*S. Lloyd Teitelman, M.D.*

ESOPHAGUS AND MEDIASTINUM

Diagnosis and Treatment of Congenital Atresia of the Esophagus (Diagnose und Behandlung der angeborenen Oesophagusatresie). H. KRAUSS and K. BETKE. *Deut. med. Wschr.*, 1955, 80: 465.

CONGENITAL ATRESIA OF THE ESOPHAGUS is more frequent than it is usually thought to be (1 to 1,000 to 2,000 of deliveries). Very often it will be missed and diagnosed as aspiration pneumonia. The sooner the right diagnosis is established the better the surgical treatment can be accomplished.

Of 12 patients with congenital atresia of the esophagus 10 were operated on for anastomosis. Four of these died afterward from pneumonia, 3 because of aspiration of the barium meal. Autopsy showed necrotizing pneumonia. Therefore, the authors believe it is very important to use various contrast media for diagnosing the atresia by roentgenography. They used perabrodil, joduron, and urografin, media which are water-soluble and do not give much reaction if aspirated. If there is no tension on the anastomosis, postoperative feeding can be done through a polyvinyl tube, which is placed during the operation. The authors believe that anastomosis is superior to the stomach fistula, an operation, which was done 24 hours after the first one and without any doubts created new risks.

It was believed that good postoperative care can bring up the surviving rate, which is estimated in the world literature as 30 per cent.

—*Frank R. Lichtenheld, M.D.*

Cancer of the Entrance of the Esophagus: Total Cervical Esophagectomy Including the Larynx; Prethoracic Ileocolopharyngoplasty in One Stage (Cancer de la bouche oesophagienne, ectomie totale de l'oesophage cervical, y compris le larynx; iléocolopharyngoplastie préthoracique en un temps). ALBERT JENTZER. *J. chir.*, Par., 1955, 71: 105.

THE AUTHOR reports a case of cancer of the upper end of the esophagus treated by radical excision with previous gastrostomy and tracheostomy, followed 5 months later by a prethoracic esophagoplasty in which a piece of large intestine was used to make up the deficit. He thinks that these lesions should be re-

sected whenever possible. He discusses the actual technique with the aid of excellent diagrams and roentgenograms. —*Roger H. L. Wilson, M.D.*

The Treatment of Mediastinal Abscesses by Slitting of the Esophagus (Zur Behandlung der Mediastinalabszesse durch Oesophagus-Schlitzung). HANS GOLLMITZ. *Muench. med. Wschr.*, 1955, 97: 419.

ALTHOUGH MANY INFLAMMATORY COMPLICATIONS of the mediastinum following injury to the esophageal wall respond to antibiotic and bacteriostatic treatment, absolute reliance on these agents is not justifiable and they must be regarded only as effective and indispensable aids to the surgical treatment. The mortality rate for such complications has been considerably reduced since the advent of penicillin as an adjunct. Since Seiffert's description of his esophageal-slitting procedure in cases of mediastinal involvement, 30 years ago, most criticisms have been of the adverse type. Seiffert demonstrated that a longitudinal incision of the esophagus from the site of the perforation to the base of the abscess healed rapidly without any gross structural or functional changes of the esophagus. The endoscopic route likewise shortened the period of convalescence considerably and has gradually become more popular, although chiefly among otolaryngologists. In recent years numerous reports of successful operations by Seiffert's method have been reported.

The present writer reports 2 cases in detail in which slitting of the esophagus led to recovery from the dangerous mediastinal complications. In the first case, during an attempt to pass a spastic constriction of the esophagus about 10 cm. below the epiglottis, the esophagus was perforated. In the second case an esophageal diverticulum was suspected and the esophagus was perforated during esophagoscopy. Since external mediastinotomy is indicated only when the descending inflammation has its origin in the hypopharyngeal or tonsillar region, and as the general condition of both patients was good, no immediate operation appeared imperative. Only when recovery was delayed, subfebrile temperatures persisted, and contrast roentgenograms revealed escape of the contrast medium through the perforation into the mediastinum was a slitting operation decided upon. Immediate improvement followed.

On suspicion of mediastinal complications, the patient should be hospitalized and given energetic penicillin treatment. A large percentage of cases will respond to this treatment alone. Several antibiotics may be tried and only when definite mediastinal symptoms develop is surgery indicated. External mediastinotomy is indicated in cases in which the complication is located at the transition from the hypopharynx to the first portion of the esophagus with phlegmonous infiltration of the deep cervical musculature. The frequently associated cutaneous emphysema is not necessarily a surgical indication. In all deeper mediastinal complications a slitting operation is recommended and with proper technique involves no serious dangers. —*Edith Schanche Moore*

MISCELLANEOUS

Endobronchial Placer Mining for Neoplastic Cells. JOHN B. GREGG, BYRON M. MERKEL, and KENNETH R. CROSS. *Arch. Ophth.*, Chic., 1955, 61: 267.

THE AUTHORS present a technique for obtaining specimens at bronchoscopy for cytologic examination. A small suction cup is used and an attempt is made to actually remove small pieces of mucosa. This area is then washed with a forceful stream of saline, and the specimens collected. One of the advantages of the technique is that a cell block is made and regular fixed sections are prepared. Specimens are then handled just as in the routine surgical case, and the slides are examined in the routine manner by the pathologist without the intervention of an expensive and time-consuming "cytology laboratory." The authors believe there is a saving of many man-hours of work.

The authors present their results in a small series of cases. The accuracy of the method appears to compare favorably with reports from some of the larger cytologic laboratories in the country.

—*John C. Carlisle, M.D.*

SURGERY OF THE ABDOMEN

GASTROINTESTINAL TRACT

An Anatomic Approach to the Problem of Massive Gastrointestinal Hemorrhage. JAMES M. KANE, KARL A. MEYER, and DONALD D. KOZOLL. *Arch. Surg.*, 1955, 70: 570.

THE IMPORTANCE of the gastrointestinal bleeding problem is illustrated by the observation that hemorrhage as a cause of death has more than doubled since a previous review. The different anatomical diagnoses as to the cause of hemorrhage are listed in the order of their incidence. The protocols of 28,400 consecutive autopsies at the Cook County Hospital, Chicago, were reviewed. Massive gastrointestinal hemorrhage was found in 673 cases; in 310 cases it was the cause of death and in 363 cases it was contributory or incidental to it.

Fatal hemorrhage occurred most frequently from esophageal varices. In 97 of the 480 cases discovered hemorrhage was considered the primary cause of death.

Of 669 patients with gastric ulcers, 87 had fatal and 108 had nonfatal gastrointestinal hemorrhage. Of 531 patients with duodenal ulcers, 57 had fatal and 82 had nonfatal hemorrhage.

Of 349 patients with aneurysms 20 bled, 19 of them fatally. In all but 2 of these the aneurysm was in the aorta; in the 2 it was in the hepatic and splenic arteries.

Of 1,341 autopsies in carcinoma of the gastrointestinal tract, there was bleeding in 74, which was fatal in 17. Of 230 cases of cancer in the esophagus, 3 proved fatal. Of 597 carcinomas of the stomach, 13 bled fatally. Of 112 cases of carcinoma of the head of the pancreas, 4 of them bled fatally.

Fatal hemorrhage in diverticulitis, colitis, or gastritis was rare. In 25 cases no morphological cause could be ascribed to the bleeding. Fatal bleeding was found in all ages including the newborn period. The greatest incidence of fatal hemorrhage occurred during the fifth, sixth, and seventh decades of life. There was a 4 to 1 predilection of the male sex and the white race for fatal hemorrhage, suggesting an endocrine factor.

It has long been recognized that the aging process influences the mortality rate from gastrointestinal hemorrhage. The chronicity of an ulcerating lesion makes healing difficult. Degenerative changes in the vessels around ulcers prevent retraction and contraction. The compensation for blood loss is less effective with advancing years. Nutritional deficiencies are more frequent in the older age group.

The presence of coronary sclerosis in bleeding patients creates a dangerous combination as all factors to give maximum cardiac embarrassment may be present. Other coexistent diseases found include hypertensive heart disease, syphilitic aortitis, arteriolar nephrosclerosis, benign prostatic hypertrophy, hepatic and pancreatic lesions, goiter, and adenoma of the adrenal cortex. In the cases of bleeding peptic ulcers, a high incidence of multiple peptic ulcers was found.

The high incidence of certain coexistent diseases suggests that some conventional contraindications to surgical hemostasis may actually be indications. In other words, the effect of hypotension and blood loss on organs with a limited physiological reserve may be actually the cause of death and not the hemorrhage itself. —*Kenneth E. Sherman, M.D.*

Experimental Observations on the Etiology of Gastric Carcinoma; the Effect of Heat, Browned Overheated Fats, Food Dyes, and Carcinogenic Hydrocarbons on the Gastric Mucosa. A. C. IVY. *Gastroenterology*, 1955, 28: 345.

THIS ARTICLE summarizes the experimental observations made by the author and his colleagues on the effect of hot drinks and foods, browned overheated fat, food-coloring dyes, the prolonged feeding of known hydrocarbon carcinogen in the absence and presence of a gastric ulcer, and the detailed histologic changes following the embedding of methylcholanthrene in the submucosa of the glandular stomach. Heat has to be seriously considered because of the clinical observations made regarding the occurrence of cancer in areas of the skin which have been burned.

It was found that about 10 per cent of people can and do ingest hot food and fluid at sufficiently high temperatures that minimal injury of the gastric mucosa very likely occurs. It has been found that dogs fed hot foods over a prolonged period developed gastritis with evidences of hyperplasia and hypoacidity. "Overheated" fat has been implicated as a cause of gastric carcinoma in rats, and the experiments of the author showed that by feeding "overheated fat" to rats there was produced an increased incidence of gastric lesions and a decreased average length of life when compared to a control group of animals which were fed a diet of equivalent fat content. However, no carcinomas developed from the feeding of "overheated" fat. Since there is some evidence that a carcinogen may be produced by heating fat, there should be continued experimentation on this factor. Many substances are ingested in the daily diet, such as condiments, materials produced by browning, and natural and artificial food dyes, which may act as carcinogens. Because some dyes are known to be carcinogenic, food dyes were fed to rats. Their absorption by the gastric mucosa could be detected by the color. Seventeen dyes were found which stained the glandular stomach. Five of these seventeen dyes, after 3 weeks, caused a hypertrophic type of gastritis. Further work on this factor is needed. All processed foods should be analyzed for their content of nickel, chromium, arsenic, and copper, which are known to be carcinogenic under certain circumstances.

Because of the negative results with feeding and direct application of carcinogenic hydrocarbons to normal animals, rabbits (which always have some food in their stomach) with a chronic gastric ulcer were prepared and fed methylcholanthrene in their diet. After various periods up to 3.3 years, no evidence of

a true invasion or malignancy was found. However, when methylcholanthrene is implanted into the muscularis mucosae of the stomach of rats, it results in a variety of histologic changes in the mucosal epithelium including metaplasia and epithelial downgrowth and invasion. Twelve malignant or invasive tumors developed. It is concluded that, though gastric carcinoma has not been produced experimentally by dietary means, the results of the experiments performed have been of much value in elucidating the problem in man. The experimental and clinical evidence strongly supports the view that, unless a water-soluble carcinogen exists, the prevention of gastritis and of gastric ulcer should greatly decrease the incidence of gastric carcinoma. —*David T. Petty, M.D.*

Cathepsin and Pepsin After Gastric Resection and Gastrectomy (Kathepsin und Pepsin nach Magenresektion und Gastrektomie). H. G. PFISTERER. *Langenbecks Arch. u. Deut. Zschr. Chir.*, 1955, 280: 123.

THE FACT that patients with gastric resections have a relatively good utilization of protein has lead the author to undertake determinations of gastric cathepsin and pepsin in patients who underwent gastric resection procedures of various kinds.

The ferment activity of the gastric juice in increasing dilutions was measured by the disappearance of the substrate (edestin, a vegetable globulin).

Several groups were studied:

1. In 10 normal persons it was shown that peptic and catheptic proteolysis curves are of the same pattern, cathepsin having a somewhat broader range of effect and being active in higher dilutions than pepsin.

2. In 40 patients with duodenal and gastric ulcers preoperatively, increased activity of both pepsin and cathepsin was demonstrated.

3. Thirty-seven of 40 patients with duodenal and gastric ulcers were again studied 8 to 22 days after they had had a partial gastrectomy (resection of antrum only, Billroth 2 type of operation). Pepsin values were markedly decreased, whereas cathepsin showed unaltered activity.

4. Eighty patients who had had the same resection as in group 3 were examined 5 years or more postoperatively. Cathepsin values had decreased somewhat but were still within normal ranges. The values for pepsin had shifted into higher dilution ranges, thus approaching but not quite reaching the ranges of increased activity of group 2.

5. In one-half, two-thirds, and subtotal gastric resections for gastric ulcer or carcinoma (total of 32 patients) a decrease of both catheptic and peptic activity was noted to be proportional to the extent of the resection toward the cardia, the loss of catheptic activity being less pronounced.

6. In 6 patients resection of the cardia with esophagoantrostomy had been performed. The curves for both ferments resembled those of the normal persons of group 1, with only a slight shift to lower dilutions, cathepsin ranging from dilutions of 64 to 512, and pepsin ranging from 16 to 128, as compared with normal ranges of 64 to 1,024 and 32 to 256 for cathepsin and pepsin, respectively.

—*Fritz H. Moser, M.D.*

Acute Massive Hemorrhage and Acute Perforation in Peptic Ulcer. HAROLD D. HARVEY. *Surg. Clin. N. America*, 1955, 35: 369.

HEMORRHAGE and perforation are the usual indications for emergency operations on the stomach and duodenum. A study of these two conditions undertaken at the Presbyterian Hospital, in New York, is presented.

Massive hemorrhage. It is difficult to compare patients with gastrointestinal bleeding and to evaluate the results obtained by different forms of therapy applied at the same or different institutions. A concept of acute gastrointestinal bleeding applicable to clinical material is neither easily reached nor defined. The patients in the present series demonstrated hemorrhage of such magnitude that symptoms of blood loss developed. More than 2 liters of blood were required to replace the loss. Any surgical procedure performed was carried out as an emergency measure.

A total of 974 patients with acute gastrointestinal bleeding were treated between the years of 1940 and 1953. An increase of the operability rate was noted and a decrease in the hospital mortality rate of about one-third was observed among patients treated after 1947.

A total of 85 patients subjected to emergency gastric resection with a mortality rate of 18 per cent, reflects mainly the poor cardiovascular status present. It should be mentioned also that about three-fourths of these patients were beyond the age of 50 years.

Of the patients that survived surgery, 85 per cent obtained satisfactory results and were free of symptoms. In 11 patients the results were not satisfactory; in 5 of these recurrent hemorrhage was manifested.

Since multiple pathologic conditions complicated the picture of hemorrhage, it is not feasible to draw conclusions by a comparison of medically or surgically treated cases.

It is important to establish a differential diagnosis between peptic ulceration, blood dyscrasia, and liver disease with esophageal varices. Adequate blood replacement, localization of the source of bleeding, and trial conservative management are essential factors of treatment.

Surgical intervention is indicated in the presence of prolonged or recurring hemorrhage, when bleeding is so great that the maintenance of an adequate blood volume is difficult. It is also indicated in poor risk patients, and in those cases in which a history of chronic peptic ulceration suggests that resection would be advisable even in the absence of bleeding.

If peptic ulceration is found at operation, exposure and control of the bleeding point are advocated. If no source of bleeding is demonstrated and exploration of the distant duodenum, esophagus, and small bowel is negative, resection is justified by the not infrequent presence of shallow ulcerations of the gastric mucosa, usually not detectable at the time of surgery.

Acute perforation in peptic ulcer. Eighty patients with perforated peptic ulcer were operated upon within a five-year period, about one-third of them being emergency resections. No deaths were reported in this group and the postoperative course was generally smoother than that in cases with simple closure of the perforated ulceration.

The author considers simple closure a life-saving measure, but that it constitutes the first step of a two-stage operation, the second stage being gastric resection or another operative measure most suitable to the particular case. The interval between the two stages provides sufficient time to determine whether further definitive procedures should be undertaken.

The general course of patients after a simple closure is illustrated by 200 cases seen at the same institution and previously reported. About three-fourths of the patients remained symptomatic throughout the years following the operation, and 5 per cent of them were complicated by re-perforation or hemorrhage.

In 35.5 per cent of these cases further surgical treatment was required some time after the simple closure had been performed.

—Néstor S. Martinez, M.D.

Lymphosarcomas of the Small Intestine (Les lymphosarcomes du grêle). P. HILLEMAND, E. CHÉRIGIÉ, R. VIGUIÉ, R. BOURDON, and Others. *Sem. hôp. Paris*, 1955, 31: 105.

WITHIN a relatively short period of time the authors observed 5 cases of lymphosarcoma of the small intestines, and in 3 of these they were able to make a correct diagnosis before the operation. In the first patient the tumor was located in the third portion of the duodenum; in the second patient, Treitz's angle was involved; in the third patient the jejunum and ileum were the sites of the tumors; in the fourth patient only the jejunum was invaded; and in the fifth patient the neoplasm was at the ileocecal junction.

Two types of lymphosarcomas of the small intestines may be distinguished: (1) lymphosarcomas which develop from lymphoid tissues, consisting of lymphocytomas formed by adult cells, and malignant macrocellular lymphosarcomas; and (2) reticulosarcomas which are formed by nondifferentiated tumors, reticuloendotheliomas, and histiocytic sarcomas.

The tumors in the 5 cases presented were found in one woman, aged 56, in another woman aged 65, and in 3 men whose ages were 30, 40, and 42 years, respectively.

The clinical picture is dominated by pain, anemia, and loss of weight, the symptoms being isolated or combined one with another. The onset is always insidious. The pain is intensive, mostly intermittent, and suggestive of a gallbladder attack, a gastric lesion, appendicitis, or colitis. Nausea, occasional vomiting, and subfebrile temperature are present in some cases.

After the ingestion of a small quantity of barium meal, x-ray exposures should be made at thirty-minute intervals. If an abnormal image is obtained, the pictures should be taken every 5 minutes. The authors stress the fact that not infrequently multiple lesions are visualized.

Lymphosarcomas of the small intestines occur with lesser frequency than is generally assumed. Three types of lymphosarcomas of small intestines may be distinguished: polypoid and nodular, intraparietal or annular, and aneurysmal or diverticular.

Extensive extirpation is the method of choice. If resection is impossible, a sidetracking operation is indicated. Although the tumors are radiosensitive, only a temporary amelioration may be expected from irradiation. The results of surgical intervention combined with radiotherapy are equally disappointing. Nitrogen mustard may be administered, starting from 6 to 8 weeks after irradiation, but the results are not very encouraging. *—Joseph K. Narat, M.D.*

Rupture of the Duodenum Due to Nonpenetrating Abdominal Trauma. JOSEPH R. WILDER. *Am. Surgeon*, 1955, 21: 328.

RUPTURE OF THE GASTROINTESTINAL TRACT accounts for 10 per cent of the cases of ruptured abdominal viscus from nonperforating trauma. Only 5 to 10 per cent of such ruptures are in the duodenum, and the mortality rate from this injury is between 65 and 95 per cent. In the small intestine, the fixed portions are the most commonly affected, i.e., the duodenum, the first segment of the jejunum beyond the ligament of Treitz, and the terminal ileum. Rupture may result from the crushing of the viscera against a fixed structure, such as the spine, from tearing of the bowel at its mesenteric attachment, or from the sudden increase in intraluminal pressure with gas or fluid trapped in a bowel segment.

Delayed onset of the symptoms is common, the patient being relatively symptom-free for as long as 12 to 24 hours after the trauma. Diagnosis is then suggested by the onset of clinical signs and symptoms of peritonitis. Free air under the diaphragm is demonstrated in less than a third of the cases of small bowel perforation, compared to an incidence of 80 per cent in duodenal and stomach perforations and as high as 100 per cent in colon perforations. Therefore, no reliance should be placed on negative x-ray findings, for the mortality rate increases with the interval between the trauma and surgical treatment.

The case of a 2 year old boy whose mother found him pinned beneath an artificial wooden fireplace is reported. At the hospital, an hour later, the boy appeared ill, but abdominal examination was negative. Six hours later, there was some abdominal tenderness and guarding, with absent bowel sounds. Laparotomy revealed rupture of the anterior wall of the second part of the duodenum, and simple closure was performed. Convalescence was complicated by a draining duodenal fistula from the fifth to twelfth postoperative day and a bacteremia on the sixteenth day, but recovery was complete after 34 days of hospitalization. *—Stanley W. Tuell, M.D.*

Cancers of the Duodenojejunal Angle (Sur les cancers de l'angle duodéno-jéjunal). P. HILLEMAND, J. PATEL, E. CHÉRIGIÉ, C. NARDI, and Others. *Presse méd.*, 1955, 63: 445.

THE RARE LESIONS discussed are usually adenocarcinomas which form a napkin-ring type of stricture resulting in a secondary megaduodenum.

Clinically, two important symptoms are present: pain and vomiting. Early epigastric pain is present in 83 per cent of cases, either continuous pain or postprandial attacks occurring 3 to 4 hours after meals. Vomiting occurs later in the evolution of the lesion and the emesis is abundant, bile-stained, and gradually more frequent. Rapid impairment of the general condition and anemia are frequent findings. Hemorrhages are rare.

Radiologically, these lesions are characterized by duodenal dilatation, delayed or absent transit of the radiopaque media into the jejunum, and by the direct outline of the lesion. At times the lesion takes the form of a complete obstruction or a narrow passage with an irregular filling defect. Only small amounts of barium should be used to avoid hiding the angle behind the stomach. Films taken in the decubitus position, with the aid of compression, facilitate visualization of the entire duodenum. Occasionally, in the presence of only slight changes, the administration of atropine or a splanchnic bloc will help to bring out the slightest segmental rigidity by the relaxation of the bowel that they induce.

In the surgical treatment of these lesions, several anatomical points should be kept in mind: (a) the proximity of the superior mesenteric vessels and of the angle of Treitz, (b) the presence of the first relay group of lymph nodes draining the angle, in the left portion of the root of the mesentery (these must be removed); (c) occasional involvement by the tumor of the transverse mesocolon necessitating a wider excision; (d) the absence of adhesions of the duodenum to the aortomesenteric pinchcock.

The authors advise freeing the duodenojejunal segment from left to right, uncrossing the duodenal stump from the aortomesenteric pinchcock, and performing a supramesocolic side-to-side duodenojejunostomy. The jejunum is brought up through an avascular area in the transverse mesocolon.

Four cases are presented. In 2 cases the lesions were extensive lymphosarcomas and inoperable. In the remaining 2 cases the lesions, both adenocarcinomas, were resected with use of the technique described. One patient died postoperatively and the other was alive and well a year after the operation.

—René B. Menguy, M.D.

Congenital Defects in the Pelvic Parasympathetic System. ORVAR SWENSON. *Arch. Dis. Childh.*, Lond., 1955, 30: 1.

THE AUTHOR'S earlier studies on children with congenital megacolon who had undergone transverse colostomy, in addition to ballooning of the colon, indicated that these patients had a segment of colon without peristaltic activity. A technique was evolved which consisted of resection of the rectosigmoid and rectum with anastomosis. This procedure was tested on laboratory animals, and then utilized on patients with gratifying results.

In a series of 150 cases, absence of ganglion cells has been a constant finding. The most important point in the history was that of the duration of symptoms from birth. Barium enema was confirmatory, except in newborn babies and infants, in equivocal cases and in children who had had a transverse colostomy early in life. In such cases, biopsy of the rectal wall through the anal canal and examination for ganglion cells were helpful in diagnosis.

Seventy-five per cent of patients are treated by resection without preliminary colostomy, which is reserved for extremely ill patients and for infants. Colostomy should be done in the left colon at the aganglionic-ganglionic junction so that it can be included in the subsequent resection.

Preoperative preparation includes daily enemas and no chemotherapy. Telescoping types of procedure have been abandoned. It is advisable to free the splenic flexure and divide the left colic artery. Two infants with the entire colon aganglionic underwent colectomy with ileorectosigmoidostomy, with good results. The anastomosis must be water-tight to prevent pelvic infection. Of 150 patients, 3 developed leaks at the anastomotic site.

Postoperatively, patients did uniformly well without laxatives or enemas. Among 20 patients operated upon during the first 6 months of life, there were 4 deaths; among the remaining 130 patients, there was 1 death.

Children with Hirschsprung's disease tolerate gastroenteritis poorly, and should be treated by parenteral fluids and colonic irrigations. Fecal incontinence has not occurred in this series, nor has impotence in 6 adult males.

Cystometrograms are performed preoperatively, if feasible. Bladder and ureter abnormalities are probably caused by the same malformation in the pelvic parasympathetic system, which is responsible for the colon lesion. Resection of the bladder neck is advised for patients with megaloureters and megalobladder occurring in the absence of mechanical obstruction of the urinary tract. Such bladders are relatively aganglionic. Some patients have megaloureters and megalobladder with normal ureteral peristalsis, and others have megaloureters with normal bladders and absence of, or abnormal, ureteral peristalsis.

—S. Lloyd Teitelman, M.D.

The Management of the Complications of Diverticulitis of the Colon. HOWARD A. PATTERSON. *Surg. Clin. N. America*, 1955, 35: 451.

THE FREQUENCY of diverticulosis is realized and the need for surgical intervention in complicated diverticulitis becomes evident in our progressively older population. Improvements in anesthesia, antibiotics, preoperative and postoperative care have lowered the operative risk, but careful management including multiple-stage operations is required to maintain it at that level. The acute major complications of diverticulitis requiring surgery are discussed:

Perforation. Acute perforation of rapid development is an uncommon, frequently misdiagnosed abdominal catastrophe, occurring mostly in extremely ill male patients. On exploration it is difficult to locate the site of perforation in the mass of friable inflammatory tissue, and the application of local corrective measures is not often feasible. Although treatment with antibiotics and drainage through another incision may be sufficient, it is probably best to resort to a right transverse colostomy.

Slower-occurring perforations may remain localized and lead to an inflammatory mass. Usually there is improvement under conservative therapy. These perforations may progress to form abscesses that drain either spontaneously into or through the adjacent organs, or have to be drained surgically. With drainage into the bowel, the abscess tends to resolve; drainage into the bowel through the abdominal or perineal walls tends to create fistulous tracts. The female pelvic organs may be involved (mostly on the left side) by

inflammatory masses secondary to a diverticulitic perforation.

Distressing urinary symptoms of sigmoidovesical fistulas and frequent flare-ups of the sigmoidocutaneous variety warrant operation for relief. In the latter, local excision of the tract leading to the skin, with closure of the bowel opening, is a hazardous undertaking and should be avoided in favor of a multiple-stage resection.

When diverticulitis of the sigmoid is extensive or severe enough to require resection, the use of a preliminary, proximally located colostomy should be considered, to lower the operative mortality rate. It is the author's belief that one-stage resections can be successfully carried out but the procedure should be limited to carefully selected and prepared patients.

A preliminary colostomy is located on the right, to avoid interference with further procedures. Marked improvement may encourage the patient and the surgeon to try re-establishment of the fecal stream, but after closure only about one-third of patients will remain improved.

Resection is best carried out after a waiting period of between 3 and 6 months, except in cases in which the presence of a carcinoma has not been excluded, when earlier resection is definitely indicated. To remove all of the inflammatory process, the splenic flexure of the colon is mobilized frequently and end-to-end anastomosis is carried out in the region of the pouch of Douglas. Below this point diverticulosis is absent; above this point small areas of diverticulosis can be left below the anastomosis provided they are not actively inflamed. The author prefers an open end-to-end anastomosis with an inner row of locking catgut sutures and an outer row of silk. If a noncancerous sigmoidovesical fistula is present, repair of the bladder wall is indicated when resection is carried out. Although closure of the colostomy can be performed within 10 days, a delay of 4 to 6 weeks is recommended.

Obstruction usually develops slowly and follows repeated attacks of diverticulitis. Rarely, in older people, it has to be differentiated from volvulus and cancer—the more common causes of acute fulminating obstruction. When obstruction occurs, proximal colostomy and multiple-stage resection is recommended. Decompression by an intestinal tube in the presence of a competent ileocecal valve may mean disaster and cecostomy only rarely may produce enough decompression.

Carcinoma and diverticulitis. The two conditions coexist often enough to create a diagnostic problem. When in doubt, resection should be performed at an earlier date, particularly in patients with repeated bleeding, obstruction, atypical x-ray findings, or those who do not improve under medical management or following colostomy.

Bleeding. The actual source of bleeding is not demonstrable at operation or under examination of the specimen, and a skeptical attitude regarding bleeding from diverticulitis seems justified. Those who teach young surgeons should repeatedly caution them to be very hesitant about accepting diverticulosis or diverticulitis as the source of important bleeding. Any other attitude will often lead to dangerous delay in finding the real source. —*Nestor S. Martinez, M.D.*

Treatment of Hirschsprung's Disease with Entire Colon Involved in Aganglionic Defect. ORVAR SWENSON and JOHN HERBERT FISHER. *Arch. Surg.*, 1955, 70: 535.

THE CASES OF 2 patients with deficient Auerbach's plexus ganglion cells throughout the colon are presented. Both infants were admitted to the hospital because of abdominal distention and vomiting. Roentgenograms taken with the aid of barium revealed the colon to be essentially normal in size, the abdominal distention being due to small bowel dilatation.

The diagnosis was established at the time of laparotomy by biopsy of the right colon and was confirmed by rectal biopsy. The initial procedure was a loop ileostomy when the infants were a few days old. By making the ileostomy proximal to the physiologically obstructed colon, normal function of the alimentary tract was obtained. After several months of normal development, the ileostomy was resected and a total colectomy performed. The distal end of the ileum was pulled through the inverted rectum and anastomosed to the anus.

Both infants responded well postoperatively. There were as many as twelve stools a day initially, but in a few weeks these decreased to four loose movements a day, and the gain in weight and growth compare favorably with standard infant development.

This operation removes the functional obstruction caused by the long segment of aganglionic bowel. It is advisable to determine by biopsy whether the terminal ileum has normal ganglion cells before anastomosis is made, since it is conceivable that the aganglionic process may extend into the ileum.

—*Kenneth E. Sherman, M.D.*

Observations on Cancer of the Colon and Rectum in Connecticut; an Analysis Based on 5,572 Proved Cases. EDWARD J. OTTENHEIMER and ASHLEY W. OUGHTERSON. *N. England J. M.*, 1955, 252: 561.

THE CONNECTICUT Tumor Registry has now been functioning for 19 years. It is operated by the Division of Cancer and Other Chronic Diseases of the State Department of Health, in co-operation with the Connecticut State Medical Society, and 28 general hospitals representing 93 per cent of all the general-hospital beds of the State. Observations based on a study of accumulated data reflect the work of several hundred surgeons in both small and large communities. An exhaustive analysis was completed of all cases of cancer of the colon and rectum from 1935 to 1949. All the statistical material was compiled in the Division of Cancer and Other Chronic Diseases of the Connecticut State Department of Health.

Cancer of the colon and rectum is the most common cancer encountered in Connecticut. From 1935 to 1949 there were 46,929 cases of cancer submitted to the Registry; of these, 7,699 (16.4 per cent) occurred in the colon and rectum. Breast cancer was second in frequency, with 6,476 cases, or 13.7 per cent of the total. Cancers of the cervix and lungs are shown only to demonstrate their comparative occurrence. There seems to be a growing impression that cancer of the lung is the most common of all cancers. In Connecticut it represents less than 4 per cent of all cases. It is true, however, that from 1935 to 1949 cancer of the

lungs increased about 300 per cent whereas the increase for cancer of all sites was approximately 140 per cent. The increase in cancer of the colon and rectum was 137 per cent, or about the same as that for cancer in general. Of the 7,699 cases of cancer of the colon and rectum, 2,127 were not proved microscopically and are not included in this report.

In this series the highest percentage of cancers occurred in the rectum and rectosigmoid. The lowest number was in the transverse colon. If the transverse colon is excepted, cancer of the bowel becomes steadily more frequent from the ascending colon to the rectum. This is the well recognized pattern commonly reported. For the entire group there was a greater proportion of localized cancer among private patients and a higher percentage of cases with remote metastases among ward patients. This was particularly true of cancer of the rectum and rectosigmoid, but not significantly so in other sites. Another strong influence on the stage of disease is the grade of the tumor. There is a striking tendency for highly differentiated tumors to remain localized. In this series over 66 per cent were of this type, whereas only 7.5 per cent of patients had remote metastases on admission. Conversely, of the grade 3 tumors, only 35.9 per cent were localized, and more than 21 per cent were associated with remote metastases. This held true for all sites in the large bowel, but particularly in the rectum and rectosigmoid, where over 70 per cent of the grade 1 tumors were localized on admission.

Radical operations for cure were being performed in a significantly higher percentage of patients in 1949 than in 1935. Of the entire series of 5,572 patients 56.1 per cent had radical surgery for cure, but the figure rose from 47.8 per cent in 1935 to 63.9 per cent in 1949. For the fifteen-year period, the rise in radical operations for cure was least spectacular in the ascending colon, because here the rate had always been relatively high (over 60 per cent). It was most apparent in the rectum and rectosigmoid, where the frequency of radical operations rose from 35 per cent in 1935 to a high of over 62 per cent in 1946. As the proportion of radical operations increased, there was a corresponding decrease in palliative procedures. "Curative" surgery was undertaken most often in the cases in which the disease was considered to be localized. The term "curative" surgery is used here advisedly and included not only radical surgery but also, in a small group of cases, limited surgical procedures performed for localized lesions, many of them polyps, which proved to be malignant on microscopic examination.

In the fifteen-year period there were 3,470 radical operations with 608 deaths, or an operative mortality of 17.5 per cent. This figure dropped from 33 per cent in 1935 to 9.4 per cent in 1948; in 1951 it was only 6 per cent. The decrease applied almost equally to all sites in the large bowel, and there was no statistically significant difference between private and ward patients. Operative mortality was lowest when radical operations were performed in the localized stage of the disease. If there was regional involvement, or when radical surgery was attempted in the presence of remote metastases, the rate increased rapidly. As the number of radical operations increased in a given hospital, the operative mortality became lower.

Five-year results were available for the years 1935 through 1944. Only 1.6 per cent of patients were lost to follow-up study during the first five years after diagnosis. In the ten-year period there were 2,797 patients, of whom 21.3 per cent survived for five years or more and 19.4 per cent were living and apparently free from cancer for a similar period. Even though this is a low over-all salvage, from 1935 to 1944 the survival rate increased over 55 per cent, and the cure rate over 51 per cent. The survival and cure rates for females were significantly higher than those for males. There was a general decrease in five-year survival rates with increasing age, and this was true for both males and females. The grade of the tumor apparently had a decisive effect on the end results, although the number of tumors graded suggests that conclusions be drawn cautiously. In the transverse colon, the number of Grade 1 tumors was too small to be statistically trustworthy, but in all other sites the difference in both survival and cure rates between grade 1 and grade 3 tumors was noteworthy. In the rectum and rectosigmoid, for example, the survival rate was 36.3 per cent for grade 1 tumors, and only 8.5 per cent for grade 3 tumors. Of 1,373 patients who had radical surgery for cure, 36.9 per cent survived for five years or more. Only 2.1 per cent of patients who had radical surgery for palliation survived for five years. Of those who had limited surgery for cure, 40.1 per cent survived for five years.

Much of what has been said might be epitomized by the postulation that the ideal patient with cancer of the large bowel is a woman, seventy-five years of age, who is a private patient, who has a localized lesion in the ascending colon of grade 1 malignancy, and who has survived the radical operation for cure.

Progress seems to have followed largely from the ability of more and more surgeons to perform radical operations with a steadily decreasing mortality. Although further progress may be anticipated along this line, any material change for the better in end results must await a plan for detecting more cases of cancer of the large bowel in its localized stage. This may not occur until the biologic characteristics of cancer in general, and of the colon and rectum in particular are better understood. —*Charles Baron, M.D.*

Congenital Multiple Polyposis of the Rectum and Colon (Poliposis multiple congenita recto-colica). S. VAZQUEZ MARTIN. *Cir. gin. urol.*, 1954, 8: 281.

A THOROUGH REVIEW of multiple polyposis is undertaken and the term "congenital multiple polyposis" is preferred to the multiple synonyms found in the medical literature.

The theories that attempt to explain the production of familial polyposis are reviewed from the concept of "sui generis" proliferative reaction of the colonic epithelium to the concept first postulated by Cripps in 1882—a proliferative diathesis transmitted as a Mendelian dominant trait.

Recognizing multiple polyposis as a true precancerous condition, it is important to establish a working criteria of malignancy. Excluding the cases of clinically suspected cancer, with lymphatic and/or vascular spread, the author adheres to the concepts of anaplasia, distorted architecture, and local inva-

sion, requiring at least two to admit the malignant nature of a tumor. In the cases of villous polyps, formed by tall epithelial cells with nuclear hyperchromatophilia and polymorphism, a suggestion of malignant degeneration is recognized, but a lack of rupture of the basal layer with infiltration of epithelial cells precludes the establishment of a definite diagnosis of cancer.

When considering the problem of malignancy, three clinical facts become evident:

1. Polyps in general and those of multiple polyposis in particular tend to present carcinomatous degeneration.

2. The increased incidence of gastrointestinal malignancies in some families is more pronounced in cases of multiple polyposis.

3. Polyps are frequently associated with carcinomas of the gastrointestinal tract, giving room to the hypothesis that all these cancers originate in preexisting polyps.

To illustrate the therapeutic problems encountered in this condition, the case of an 8 year old patient with associated rectal prolapse is presented. A conservative operation, similar to a Whitehead procedure, was performed—removal of a 23 cm. cylinder of rectal and sigmoid mucosa with preservation of the internal sphincter and the muscular layers of the bowel. The upper edge of the mucosa was sutured to the anal skin, the muscular layers being folded in an accordionlike fashion, and the folds being anchored with 8 interrupted nonabsorbable sutures. Two years later, after acute intussusception of the cecum into the colon was reduced by barium enemas, 9 cm. of ileum and 35 cm. of colon were resected, a side-to-side ileocolostomy being performed at the splenic flexure.

It is concluded that in treating this disease, particularly in children, some compromise takes place on the part of the surgeon, since palliative measures are not sufficient and curative measures are usually too radical. It is generally accepted that resection is indicated, but a difference of opinion arises when the extent of the resection and the time when it should be performed are determined. In treating children the author agrees that ileorectostomy and fulguration are indicated in the absence of carcinoma of the rectosigmoid.

It is postulated that the method of resection of the colonic mucosa here described, which was made easier in this case by the presence of prolapse, may in selected cases give better results than those obtained by means of fulguration.

—Néstor S. Martínez, M.D.

LIVER, GALLBLADDER, PANCREAS, AND SPLEEN

Bacteriologic Studies of the Human Liver. JOHN F. PERRY, JR., BERNARD HERMAN, PETER J. ODENBRETT, and ARNOLD J. KREMEN. *Surgery*, 1955, 37: 533.

IN 39 PATIENTS liver biopsies were taken for culture at the time of laparotomy done for a variety of intra-abdominal diseases. In 3 of these, portal venous blood was taken for culture. The portal blood specimens were transferred immediately to a culture tube containing 10 ml. of thioglycollate broth. The liver specimens were incubated overnight at 37 degrees C and then transferred to thioglycollate broth. Additional cultures were made on tryptose phosphate broth, on blood agar plates, and eosin-methylene blue agar plates. The cultures were examined daily for growth. The blood agar and eosin-methylene blue plates were discarded after 4 days. The broth cultures were incubated for at least 31 days before they were discarded. At the end of 7, 14, and 21 days, smears were made from the thioglycollate broth and the tryptose phosphate broth culture. Subcultures to the blood agar plates were made at the same time.

In only 2 patients were positive cultures obtained and both were thought to be contaminated. In 37 of the 39 patients all of the cultures were sterile.

These data support the conclusion that viable bacteria are not present in the human liver and portal vein under normal circumstances as they are in the dog. *Frederick W. Preston, M.D.*

Treatment of Pancreatic Fistulas. HELGE HELLSTEN and OLOF OLSSON. *Acta chir. scand.*, 1955, 108: 443.

IN THE PRESENT ARTICLE the authors discuss the management of pancreatic fistulas. They report briefly 2 cases in which the treatment consisted of anastomosis of the fistula to the stomach, and pancreatogastrostomy. Both patients recovered and remained well.

The various causes of pancreatic fistula are enumerated. Loss of fluid and electrolytes, reduction in enzyme supply for digestion, and distressing skin effects are outstanding signs. Alkaline reaction of the secretion and the presence of one or more pancreatic enzymes are the surest diagnostic factors. Fistulography is important, both in the diagnosis and in deciding upon the best method of treatment. Most fistulas will close following conservative management. Restoration of fluids and electrolytes, the use of local applications of pastes of various sorts, suction drainage of the fistula, and the administration of banthine or probanthine are the mainstays of conservative therapy.

—Donald C. Geist, M.D.

SURGERY OF THE BLOOD AND LYMPH SYSTEMS

BLOOD VESSELS

Obliterative Lesions of the Peripheral Arteries (Les oblitérations artérielles périphériques). J. BAUMGARTNER and G. MOTTIRONI. *Helvet. chir. acta*, 1955, 22: 2.

This treatise deals with the entire problem of obliterative arterial diseases and their consequences. Of particular interest is the convenient classification of arterial disease. The photomicrographs of thromboangiitis obliterans included are remarkable for clarity and teaching quality. The authors consider arterial obliterations under four categories: external compression (exostoses, bandages, tourniquets, fractures, tumors, cervical ribs); mechanical disturbances (emboli, thrombi, foreign bodies); prolonged spasm (Raynaud's phenomenon); and autochthonous occlusion (alterations in the surrounding tissues, as in fibrous stenosis). In some syndromes there appears to be considerable overlap of these categories.

Most inflammatory lesions appear to have a complex etiology based not only on infection but often on endocrine and allergic factors.

The degenerative lesions are critically reviewed from the point of view of recent experimental work. An interesting question is raised regarding the occurrence of segmental occlusions in arteriosclerosis; i.e., whether they are due to segmental spasm, local thrombosis, or both.

The various techniques of examination are reviewed, and useful pointers in arteriography are described.

The treatment of arterial disease is described with discussions on the anatomic and physiologic bases of the different modes of treatment. Conditions which must prevail to qualify a patient for direct arterial surgery are carefully described.

The monograph is a highly useful review of an interesting and rapidly growing field.

—*Harold Laufman, M.D.*

The Digital Arteries of the Hands in Raynaud's Disease. R. B. LYNN, R. E. STEINER, and F. A. K. VAN WYK. *Lancet*, Lond., 1955, 1: 471.

THE BLOOD VESSELS of both hands were studied by means of arteriography in 23 patients (14 women and 9 men) who had intermittent spasm and color changes of the fingers. There was almost complete correlation between the arteriographic findings and the nutritional state of the fingers. The patients showing paronychial ulceration or infection, pulp atrophy, ridged brittle finger nails, or phlyctenular gangrene were those in whom arterial obliteration was demonstrable by arteriography. The study revealed that vascular spasm may develop not only in hands in which the digital arteries are structurally altered but also in hands with anatomically normal vessels. The authors believe that the term "Raynaud's phenomenon" should be used to designate intermittent spasm of the digital arteries without clinical complication and with a normal arteriographic appearance of the digital arteries. "Thrombotic digital artery disease" is a better term when local nutritional changes are present and there is arteriographic evidence of obliteration of the digital arteries. —*Robert A. Nabatoff, M.D.*

Resection and Replacement with a Venous Autograft of a Dissecting Aneurysm and Traumatic Obliterating Arteritis (Traitement d'un anévrisme disséquant et d'une artérite oblitérante traumatique par résection suivie d'autogreffe veineuse fraîche). C. MENTHA. *Helvet. chir. acta*, 1954, 21: 343.

THE ARM of a 43-year-old man was caught in a transmission shaft. Immediate loss of strength and pain in the entire arm resulted. A large hematoma extended from the shoulder to the middle part of the forearm, but the roentgenogram showed no injury to the bone. Treatment for contusion of the muscle was instituted. After a period of 3 weeks, pain and weakness persisted and oscillometry showed greatly diminished amplitude of pulsations. General vasodilators were of no avail.

Two months after the accident the patient was totally disabled. The entire extremity, including the thenar and hypothenar eminences, was atrophied. No arterial pulse was palpable at the wrist, elbow, or axillary fossa, and the causalgic pain was intolerable. The fingers were cold, cyanotic, and hyperhidrotic. Arteriography showed a zone of obliteration astride the axillary and humeral arteries with a lacework of irregular opacities appearing in the area of the arterial defect.

After a second stellate ganglion block the pain diminished, sleep returned, and disability decreased 50 per cent, but there still remained an intermittent claudication on effort since the patient could not grasp an object without the onset of great fatigue after a few minutes.

In view of the future possibilities the result was considered unsatisfactory. Therefore a 7 cm. segment of the obliterated artery was resected and replaced with an 11 cm. venous graft from the left internal saphenous vein, by end to end anastomosis. The vigorous pulsations of the radial artery certified to the immediate operative success. The pathologist's diagnosis was that of traumatic dissecting aneurysm and arterial obliteration.

Postoperatively, the patient's ability to work has been completely restored. He is able to do the heaviest type of work without ischemia of effort. The pulses are perceptible at all levels. The temperature of the left hand is 2 degrees above that of the right hand, because the arteriectomy abolished the vasoconstrictor fibers.

It is concluded that general vasodilators are without effect in obliterating arteritis, regardless of the etiology. Although hyperemic therapy relieves the symptoms it does not abolish the ischemia of effort. The ideal treatment of acute arterial contusions consists of resection of the obliterated artery, followed by the application of a fresh venous autograft.

—*Sidney Smedresman, M.D.*

Experimental Vascular Grafts; Arterial Homograft Degeneration. LLOYD M. NYHUS, EDMUND A. KANAR, HORACE G. MOORE, JR., EVERETT J. SCHMITZ, and Others. *Am. Surgeon*, 1955, 21: 289.

MOST HOMOGRAFTS fulfill their purpose by providing a nonviable framework over which the host's living tissue may grow. The most notable exception is the cornea, which derives its nourishment from the aqueous humor, rather than the blood, and hence provokes no immune response in the host, and the grafted tissue continues to live. The longevity of cartilage homografts is likewise attributed to their relative avascularity.

Arterial homografts exhibit degeneration of the intima, the smooth muscle cells, and the elastic tissue, in that order, and the first two are rapidly replaced by fibroblasts from the host vessel. The inner layer of fibroblasts forms flattened endothelial cells. The elastic fibers remain for a long time as the only remnants of the graft. This tube of scar tissue functions well as a blood conduit, but the experiments outlined indicate that further degenerative changes occur with development of atheromalike plaques and calcification.

Fresh and preserved thoracic aorta homografts of various lengths were transplanted to 41 young pigs. The length of the graft was not found to be a significant factor in determining the type or degree of degenerative changes. Calcific plaques were about equally distributed through involved grafts, regardless of length.

The high incidence of relatively early degenerative changes in this series may be related to the anatomic site chosen—the thoracic aorta lying in a less vascular bed than the abdominal or peripheral major vessels usually used in such experiments. Pressure changes within the chest, or stimulus to calcification by removal of a rib were other possible factors considered.

Preserved grafts showed more severe degeneration than did fresh grafts in the same length of time following transplanting, but there was no correlation between the degree of degenerative change and the length of time of preservation of the graft. Cellular viability of the graft is not necessarily correlated with the absence or retardation of degenerative changes.

Vascular grafts are apparently antigenic, and this is an important factor in determining the occurrence and rapidity of degeneration.

—*Stanley W. Tuell, M.D.*

Late Results of Inferior Vena Cava Ligation. RALPH F. BOWERS and SAMUEL M. LEB. *Surgery*, 1955, 37: 622.

THE PERFORMANCE AND EFFICACY of the prevention of pulmonary emboli would suggest that ligation of the inferior vena cava is the ideal procedure for treatment of venous thrombosis of the legs and pelvis with embolism. However, follow-up studies of 33 patients whose cavae were ligated 1 to 7 years before demonstrated changes which contraindicated such routine use. The 33 patients included 22 with pulmonary embolism, 5 whose cavae were ligated prophylactically at laparotomies (presumably in cases with previous or co-existing thrombophlebitis in the legs), 1 each with phlegmasia caerulea dolens and thrombophlebitis with gangrene, and 4 who had extensive leg ulcers whose legs seemed ready for amputation.

Four of 5 deaths following the operation were due to the original disease process; one was due to a technical error.

Although the mortality rate was not excessive, the incidence of disabling sequelae was high. All patients had some edema of the legs, usually of mild degree. In 8 of 9 patients who had leg ulcers before the ligations the ulcers healed for a brief time; in 2 others permanent healing occurred. However, in 15 patients severe stasis changes with ulceration appeared in legs which were normal before the operation. In this analysis, it is implied that when severe ulceration or postphlebitic disease existed before the cavae were ligated (it is not entirely clear to the reader what element of the ulcerative tendency was static and what was ischemic) the patients were benefited, and amputations were forestalled, but normal legs suffered edema, and other stasis changes, including ulceration. One patient, who may have had Buerger's disease, developed extensive deep thrombophlebitis with cyanosis after simple ligation of varicose saphenous veins. His inferior vena cava was ligated as a measure of desperation after which the bad leg improved and the "good" leg rapidly became gangrenous and was amputated.

In summary, 15 patients were restored to their normal or near normal activities, 9 of whom have only fair capacities of locomotion. Seven patients with poor locomotion have reduced activity. Three amputees are invalids. Seventeen patients can earn their living; 8 cannot. Therefore, when the operation is indicated to interrupt a death-dealing process, vena cava ligation is acceptable. It is not a procedure of election, because two-thirds of the patients develop undesirable late effects.

—*Leonard D. Roseman, M.D.*

Hypertensive Ischemic Leg Ulcer. EGMONT J. ORBACH. *Angiology*, 1955, 6: 153.

IN 1945, Martorell directed attention to symmetric supramalleolar ulcerations in the lower third of the legs caused by stenosing subendothelial hyalinosis in hypertensive patients. According to him, the histologic substratum is in some cases an intense hyalinosis between the endothelium and the internal elastica and in others an endarterial proliferation, both of which lead to stenosis of the arterial lumen and in some cases to enlargement and nuclear multiplication of the media. As in the case of diabetic, arteriosclerotic, or thromboangitic endarteritis, the ensuing ischemia produces a necrotic ulceration. Hypertensive ischemic ulcer is a clinical entity rather than a pathologicoanatomic one.

The location of the typical ulcer is the area above the external malleolus, especially at the border of the middle and lower third. Usually ulcerations are symmetrical. The ulcer either starts as a little bluish-red spot which breaks down, or it follows a slight injury. It lacks induration of the margins, is painful and resistant to treatment, and may persist for weeks, months, or even years. These ulcers are prevalent in women.

The hypertension is always severe, with elevation of both the systolic and diastolic pressure. There are no clinical signs of segmental arteriosclerotic obstruction of the main arteries. The venous circulation is intact and the lymph vessels are unaffected. The arte-

TABLE I.—DIFFERENTIAL DIAGNOSIS (MODIFIED AFTER F. MARTORELL)

	Hypertensive Ulcer	*Arteriosclerotic Ulcer*	*Diabetic Ulcer*
Age	35 to 70	60 plus	45 plus
Sex	Prevalent in women	Both sexes	Both sexes
Distribution	Bilateral,	Unilateral	Unilateral
Localization	Anterolateral aspect of the lower leg; at the border of the middle and lower third (supramalleolar, ext. mall.)	Around malleoli, on dorsum pedis, lateral borders of feet, toes	Toes, heel, dorsum of feet, planta metatarsal region anterior aspect of tibia
Clinical aspect	Superficial	Penetrating	Penetrating, cellulitis, in surrounding lymphangitis (sepsis)
Oscillometry	Increased or normal	Decreased or absent	Normal or decreased
Peripheral pulsation	Present	Decreased and missing	Normal or decreased
Radiology	Calcifications absent; arteriogram normal	Frequent calcification; arteriogram showing segmental defects	Occasional calcification; arteriogram normal
Histology	Subendothelial hyalinosis, increase of media, stenosis of lumen	Endarteritis	Subendothelial fibrosis with hemorrhagis foci in intima and media

riograms are expected to be normal. Although the incidence of hypertensive ulcers is low, patients with severe hypertension should be cautioned to avoid mechanical and thermal injuries to their legs, in the same manner as diabetics and arteriosclerotics are trained in the care of their feet.

The treatment of the established hypertensive ulcer should be primarily conservative. Heroic measures like sympathectomy are not warranted. The concomitant enforced rest and skillful treatment of the ulcer should achieve the same results without surgery. It is the author's feeling that in selected cases thoracolumbar sympathectomy may prolong life as part of the treatment of the hypertension, but the presence of an ulcer alone is not indication for sympathectomy. The conservative treatment should be further reinforced with the use of drugs which tend to produce vasodilatation. Locally, the enzymes of varidase and tryptar produce a medical débridement of the ulceration. Antibiotic agents may help to eliminate infection. The wounds should be kept covered. Sponge rubber should be incorporated into a supporative bandage which reaches from the metatarsal region up to the area below the knee and will keep the patient ambulatory. If under this treatment the ulcer should not heal within a reasonable time, excision of the ulcer down to the muscle tissue and skin grafting should be carried out. A split skin graft of 1/12,000 of an inch has the best prospect of survival.

—LeRoy J. Kleinsasser, M.D.

BLOOD; TRANSFUSION

Theoretical Consideration of the Spread of the Hepatitis Virus by Plasma Transfusions (Données théoriques sur la diffusion des hépatites virales par les transfusions de plasma). P. CAZAL. *Vox. sang.*, 1955, 5: 20.

THE RESULTS of sterilization of plasma by ultraviolet lights are illusory, and the combination of this method with chemical antisepsis, namely, the use of beta-propiolactone, also fails to prevent virus hepatitis as a sequel of transfusion of plasma. The virus is highly contagious, so that a very small volume of contaminated plasma, added to a very large quantity of normal plasma, renders the entire fluid potentially dangerous. Latent carriers of the virus, who have no clinical symptoms and give no history of icterus, represent the main source of infection. Virus hepatitis develops only in approximately 50 per cent of contaminated recipients.

In France, a unit is represented by 330 c.c. of plasma obtained from blood diluted with an anticoagulant in the proportion of 5 to 1. For children, the following amounts are used: 40 kgm. of body weight, 200 c.c.; 20 kgm., 100 c.c.; 10 kgm., 50 c.c., and 4 kgm., 20 c.c.

To avoid a veritable epidemic of virus hepatitis, it is advisable to obtain small plasma units from little pools or, still better, from a single donor.

Coefficient of contamination represents the ratio between the number of units of contaminated plasma and the number of donors who are virus carriers. This coefficient can be used for the comparison of various methods of preparation of plasma.

The risk of contamination is reduced by withdrawal of relatively large amounts of blood, by limiting the amount of pooled plasma to from 2 to 5 liters, and by separate centrifugation of the blood from each donor. If for technical reasons so-called continuous separation of plasma must be employed, i.e., if an apparatus is used in which centrifugation and separation are accomplished concurrently, the capacity of the bowl should be small so that fractions of the pool do not exceed 2 liters. *—Joseph K. Narat, M.D.*

SURGICAL TECHNIQUE

OPERATIVE SURGERY AND TECHNIQUE; POSTOPERATIVE TREATMENT

The Anesthetist Looks at Preoperative and Postoperative Care. MEYER SAKLAD. *Arch. Surg.*, 1955, 70: 448.

THE AUTHOR emphasizes the need for closer co-operation between the anesthetist and the surgeon. Since an important part of the surgical patient's hospital experience is due to the joint efforts of the surgeon and the anesthetist, their endeavors overlap. This common responsibility places each of these partners in a position to aid the other, especially in preoperative and postoperative care. Moreover, such co-operation should engender mutual constructive criticism. The discussion reviews the areas in which this objective may be achieved.

Data are presented to summarize the findings in regard to the relationship of age, duration of surgery and physical state, to major respiratory complications, major circulatory complications, and deaths, for the years 1941 to 1950, inclusive. This information was derived from a statistical study made in 1951 by 17 qualified anesthetists representing 17 institutions in the New England area for the 5 year period from 1946 to 1950, inclusive.

Emphasis is placed upon the importance of the recovery room where the patient is under the combined care of the anesthesia and surgical services, and the plan of the Rhode Island Hospital of Providence is presented.

The recovery room still leaves a weakness in the care of the seriously ill surgical patient. Because of a busy operative schedule, several seriously ill patients leave the recovery room and are dispersed to different areas in the hospital. The patient has then been removed from the area of specialized care, one of immediate and close supervision, to the care of medical and nursing personnel whose responsibilities are wide and varied. The occasional patient whose needs are greater than the average in his nursing unit may, and does, suffer. The solution seems to be the continued concentration of seriously ill patients beyond the usual recovery room.

The Rhode Island Hospital, in planning its new building, believes that such concentration is to the best interest of the patient. The area for this purpose termed a "critical ward" or a "specialized service area" has further advantage in that the concentration of skilled services in a given area prevents dissipation of such services. The area planned is of two units, A and B, for the purpose of further subdivision of patients, depending upon their specific needs. The more critically ill, the ones that require the more constant supervision will go to unit A, and the others to Unit B. The first contains 12 beds, 10 of which are in a single large room, and the other 2 are glass-walled single rooms for patients in extremis. The second unit contains 16 beds. There are two 4-bed units so placed that they can be made into a single 8-bed unit. There are also a 3-bed and a 2-bed unit, and 3 single rooms. The nursing stations are strategically placed in these units, and a bedroom for a surgical resident is in close proximity. All units in the critical ward are served by an intercommunication system.

This philosophy is economically sound also, for it will relieve the personnel problem through many areas of the hospital. It is important that this area be adjacent to the operating rooms, and in the Rhode Island Hospital it will be placed on the floor immediately above the recovery room. At the end of the operation the determination of direction in which the patient goes becomes a medical decision. Such determination is the result of the surgical and medical opinion of the patient's immediate attendants.

Most patients will go directly from the operating room to their beds. This group will consist of patients who are awake, who have full return of their vital reflexes, and who are in excellent physical state. A large number will go to their rooms by way of the recovery room, there to await the time when it is safe to transport them. The period spent in the recovery room depends upon the time required for these patients to regain their reflexes, to become stabilized, or to await termination of the intravenous administration of fluid.

In general, the recovery room is to be used as an area for awaiting return of the respiratory reflexes, or a place where ministrations by the anesthetist (for example, tracheal aspiration) are readily available. The critical unit is to serve for the care of the seriously ill. To this ward may be brought patients suffering from any condition which requires immediate and close supervision. The area will be equipped with much of the same material available in the operating room, such as suction apparatus, bronchoscopes, and tracheotomy sets.

It is proposed that there always be in attendance in this critical ward either a senior surgical or senior anesthesia resident, but on occasion perhaps both will be required. It is perhaps best, the author feels, that the patient's private duty nurse be dispensed with. With changing techniques and changing philosophies in the care of patients, the needs of the patient can best be met by one who cares for such patients.

In short, what should be sought is the surrounding of patients with the same safeguards, personnel, and equipment which protect him in the operating room, for it is in the operating room that mechanisms are set up to handle untoward events better than anywhere else in the institution. —*Alan L. Dorian, M.D.*

ANTISEPTIC SURGERY; TREATMENT OF WOUNDS AND INFECTIONS

Present-Day Early Care of Traumatic Wounds. ROBERT H. KENNEDY. *Surg. Clin. N. America*, 1955, 35: 355.

THE GREAT IMPROVEMENTS in general surgical treatment have not been applied to the early care of

wounds. In many hospitals the emergency room is in charge of an inexperienced interne. Recognition of the extent of injuries and of the complexity of proper treatment is lacking. For those reasons, prolonged morbidity and avoidable fatalities are very apt to occur.

All accidental open wounds are contaminated by the wounding instrument, the clothing it traverses, and the skin it penetrates. During the first 6 hours after the wounding event, infection usually is absent, the contaminants may be removed, and the wound is managed as an aseptic lesion. The administration of antibiotics soon after the injury occurs may prolong that period up to 48 hours.

The principles of treatment of abrasions, incised wounds, contusions, lacerations, penetrating wounds, and perforations are stated.

Avulsion wounds may occur, in which skin flaps are attached by narrow pedicles. It is better to detach the flap, remove the fat, and to reapply it as a free full-thickness graft than to attempt to replace the flap with all its subcutaneous tissues. Too often such flaps become edematous and partially infarcted, causing great delay in healing. Animal bites should be cleansed with soap and water. Strong caustics should not be used. Human bites should be kept open, even into exposed joints.

The patient's general condition should be evaluated and shock, hemorrhage, and asphyxia corrected before proceeding to more definitive treatment. Multiple lesions should be looked for, and the effects of age or debilitating diseases antedating the injury should be studied.

Prophylaxis against wound infection should begin with instructing the laity in first-aid. Strong antiseptics should not be put in wounds. Clean dressings should be applied. Hemorrhage should be controlled by elevation of the part and by direct pressure on the wound, not by tourniquets. Penetrating foreign bodies should not be withdrawn from wounds. The principles of immobilization should be stressed.

When the patient reaches the operating room the first maneuver should be wound excision. This should be done as a major procedure—with anesthesia, aseptic precautions, scrubbing of surrounding skin, removal of grease with organic solvents, and finally, irrigation and washing of the wound itself. Devitalized tissue should be removed but not in excess of that. Then hemostasis should be secured with great care and hematomas evacuated.

Wound closure may be carried out if the wound is young, not infected, if closure will not leave great dead spaces, if great tension will not occur, and if a large amount of muscle is not damaged. If the wound is not closed it should be lightly filled, not stuffed, with fine mesh gauze. Delayed primary closure after 5 to 7 days is better than partly closing a wound of dubious state of infection over a drain. Local antiseptics should be avoided. The part should be immobilized.

Tetanus antitoxin should be used, with precautions against sensitivity, whenever previous immunization with toxoid has not been given. Penicillin therapy cannot substitute for tetanus antibodies, whether actively or passively acquired.

Antibiotics should be used only on indication according to the size, position, source, and type of wound. —*Leonard D. Rosenman, M.D.*

Injuries to the Hand in Children. JOSEPH L. POSCH. *Am. J. Surg.*, 1955, 89: 784.

THE AUTHOR reviews 187 cases of children with injuries to the hand requiring hospitalization. One hundred and eleven of the patients were boys, and 76 were girls. The etiologic factors were many and varied, broken glass being the principal cause of injury, followed by burns, doors, and sharp objects.

The diagnosis is more difficult to make in children than in adults because a crying child is less co-operative, and the evaluation of nerve and tendon injury is not readily made. Surgical procedures should be carried out in the operating room, under anesthesia, and in a bloodless field. The author uses fine cotton or silk for tendon repair, according to the technique of Koch, and fine silk for the nerves. Dressings must be secured firmly and adequately. The author believes that the patient should be hospitalized and given rectal pentothal for removal of the sutures. Although dressings are usually changed at the end of one week, the author has recently allowed four weeks to pass before removal of the initial dressing in tendon injuries.

Mangle injuries are treated by suturing the severe lacerations, evacuation of hematomas, and the application of compression dressings. Burns are treated with compression dressings and by early grafting, if needed.

Formal physiotherapy is not necessary as children usually carry on their own therapy, and are not inhibited by stiff joints or compensation rewards.

—*Ely Elliott Lazarus, M.D.*

Molten Plastic Injuries of the Hand; Report of 2 Cases. JOSEPH M. BAKER. *Plastic & Reconstr. Surg.*, 1955, 15: 233.

ANOTHER HAZARD to the hands of machine workers has been brought about with the increasing use of chemicals in industry. Molten plastic materials under high temperatures that are used in the manufacture of industrial products may accidentally penetrate the hands of the worker. The result of penetration into the hand of this molten plastic material, which immediately solidifies, causes destruction of vital structures of the hand. Damage to tissues is brought about by pressure and thermal factors of this foreign material. Molten plastic injuries to the hand differ from the grease gun injuries in that the foreign material which was accidentally introduced into the hand immediately solidifies and can be removed in its entirety; whereas the oil accumulations remain indefinitely in the tissues and cause granulomatous reactions therein. The plastic material follows deeply through sheaths and spaces. At first there is swelling, numbness, and intense pain with loss of motion of the digits. Tissues are tender, hot, and discolored when the injury is first seen.

The author presents 2 cases of molten plastic injuries of the hand. The entrance site was the palmar aspect of the hand. The left hand was involved in each case, which is similar to the grease gun injuries. Pres-

sure and thermal elements on the tissues of the hand are the destructive agents. At the time of the acute injury it is difficult to determine accurately the depth of and extent of the injury. The repair of the hand following these molten plastic injuries is not unlike that of other injuries to the hand once the process of destruction is clearly demarcated. Surface covering, tendons, muscles, and bone were all affected in these injuries. The principles that guide us in the care and management of hand injuries are basic as regards the over-all management of molten plastic injuries.

—*Edmund R. Donoghue, M.D.*

Assessment of Blood Loss in Civilian Trauma. Ruscoe Clarke, Elizabeth Topley, and Cecil T. G. Flear. *Lancet*, Lond., 1955, 1: 629.

In the present study the authors assess the blood loss in 49 civilian patients with open and closed injuries. Since pre-injury controls were impossible to obtain, the red cell volume was measured at one to four days after injury, using the radioactive P^{32} method of Reeve and Veall. The difference between the estimated normal, based on height or weight, and the measured red cell volume plus the blood transfused gave the total blood loss. All measurements were converted to whole blood to better illustrate the losses.

Hemoglobin determinations were also carried out and the lowest value from the time of admission was also used to assess the excess or deficit in volume. In a series of severe injuries all the patients whose hemoglobin fell more than 30 per cent below normal had a red cell volume deficit of at least 20 per cent below normal by the second or third day.

Limb swelling was assessed to correlate with the measured losses in closed injuries and in some open injuries. Two methods were used:

1. Immersion of the injured extremity in a tank of water and noting the water displacement. This was then compared to the displacement caused by the normal extremity and the difference taken as volume of swelling.

2. Serial measurements at 2 cm. intervals from some fixed bony landmark and the calculation of this series of cylinders. This volume is compared to the same calculation of the uninjured extremity and the difference equals the volume of swelling.

A fair agreement was found between the two methods, although the former method appeared to be the more accurate.

In 10 cases of closed injury, the following results were obtained: foot and ankle fractures showed a limb swelling of 0.15 to 0.50 liters; fractures of the tibia and fibula, from 0.25 to 1.30 liters; and fractures of the shaft of the femur 0.40 to 2.20 liters. Red cell volume measurements showed a blood loss of 0.40 to 1.70 liters in fractures of the shaft of the femur.

In the group of patients with open injuries, the evaluation of blood lost to the outside was more difficult. Clinical evaluation of the amount on clothing, stretcher, and at the scene of the accident was made. Blood lost in the operating room was measured by the weighed sponge technique. In this group of 12 patients most of the blood loss was accounted for by limb swelling. Only 3 of the patients had losses to the outside which exceeded 50 per cent of the total loss. Most of this occurred at the time of operation. The results indicate that loss to the outside is of less importance than loss into the site of injury.

Twenty-four patients are presented who had combined injuries and here the blood loss is the most difficult to assess. The losses ranged from 1.0 to 5.0 liters as determined by these methods.

The results obtained in this study of civilian injuries compare favorably with the study of Grant and Reeves on war injuries. —*John H. Davis, M.D.*

Clinical Experiences in the Early Management of the Most Severely Injured Battle Casualties. Curtis P. Artz, John M. Howard, Yoshio Sako, Alvin W. Bronwell, and Theodore Prentice. *Ann. Surg.*, 1955, 141: 285.

The authors have made a study of general surgical battle casualties in which replacement of at least one-half of their blood volume was required. The severity of the wounds was often related to the amount of blood lost, and the total loss could be grossly estimated by the volume of blood required to restore a stable circulation.

During a six-month period in 1953 there were 138 casualties requiring 5 or more pints of blood or plasma expander, representing 14 per cent of the total number of casualties admitted to the general surgical service. Of these, 27 (3 per cent of the total number of admissions) required more than 15 pints. There were 20 deaths, and it was evident that the greater the number of units of blood replacement required, the higher the mortality. The site of wounding was significant. In the cases of patients with thoracoabdominal wounds, the mortality was 26.7 per cent, with abdominal wounds 16.7 per cent, and with wounds of the extremities and chest wounds, a little over 9 per cent each.

Evacuation was carried out by ambulance and helicopter in selected cases. The latter mode of transport no doubt saved the lives of many of the most severely wounded men. The average lapse of time from injury to operation was 7¼ hours. The amounts of blood or plasma expander given during surgery were approximately the same as those given preoperatively. Hemorrhage was controlled preoperatively in all of the casualties receiving 5 to 10 pints of blood or expander. In those receiving 10 to 56 pints, hemorrhage was not controlled or only questionably controlled in 21 of 77 patients. Of 4 patients in whom hemorrhage was not controlled at surgery, 3 died; 3 patients in whom hemorrhage was controlled at surgery continued to ooze from all surfaces and subsequently succumbed. Thirty-three casualties, of the total of 138, were admitted in severe shock and required an average of 15 pints of blood. The mortality was 21 per cent.

Blood volume studies, with use of the chromium-labeled red cell method, were performed in 15 patients in the early postoperative period. Taking into consideration the volume of blood replaced, it was believed that these determinations would give a good indication of the amount of blood lost. The results showed an average volume of 80 per cent of normal after replacement therapy.

A second group of 89 patients requiring replacement of 15 or more pints of blood in the first 24 hours

was studied during 1952 and 1953. This group includes some of the casualties in the first group. The fatality rate was 44 per cent of the total, with a 79 per cent mortality among those with abdominal wounds and a mortality of 17 per cent among those with wounds of the extremities.

In both series, the prognosis could be determined better by the quantity of blood required rather than by the degree of hypotension. Among those patients with unobtainable pressure on admission, and who required 15 or more pints of blood, the mortality was 54 per cent. In a similar group receiving less than 15 pints, there were no deaths.

Renal insufficiency, oliguria, or nonoliguric azotemia occurred in 35 per cent of 43 casualties who required replacement of more than 15 pints of blood and who lived longer than 3 days. Of 122 surviving patients who received 5 or more pints, 6 developed renal insufficiency. It was apparent that this complication is seen primarily in those with extensive tissue injury.

The major cause of death in both series was the inability to maintain an adequate circulating blood volume. Blood loss from extremity wounds is usually controllable before surgery. Abdominal wounds, on the other hand, may require operative intervention to stop bleeding in a poor risk patient with marked deficit of blood volume. This, coupled with the altered physiology accompanying abdominal wounds, probably accounts for the much higher mortality in these casualties. In some patients receiving large volumes of blood a clotting deficiency developed; in some instances the condition responded to fresh blood transfusions and in others persistent oozing resulted in death.

A comparison of these statistics with some of those from World War II reveals marked improvement in mortality rates. Credit is probably due both to the shorter evacuation time and the more vigorous replacement of blood volume.

It is emphasized that resuscitation and surgery must be considered together. Control of hemorrhage before surgery or during operation may be very difficult in severely wounded soldiers. Persistent hypotension was almost invariably an indication for further transfusion to combat inadequate replacement of blood or continuing hemorrhage. —*Victor M. Bernhard, M.D.*

Therapy of Grave Tetanus (Therapeutische Massnahmen beim schweren Tetanus). L. ECKMANN. *Deut. med. Wschr.*, 1955, 80: 684.

TETANUS ANTITOXIN is capable of neutralizing only circulating toxin and not the toxin deposited in cells. Therefore the administration of antitoxin and the toilette of the port of entry must be supplemented by other therapeutic measures.

Respiratory standstill of central or peripheral origin may require tracheotomy, the administration of oxygen, and the employment of an iron lung.

The use of curare has supplanted the administration of avertin, magnesium sulfate, or barbiturates in the treatment of convulsions.

In the course of tetanus the metabolic activity of the organism is increased not only during convulsions but also when they are suppressed. To reduce this activity, artificial hibernation has proved to be of inestimable value. A retention catheter, enemas, and gastric suction may be required. Only parenteral nutrition comes into consideration when hibernation is employed. —*Joseph K. Narat, M.D.*

MISCELLANEOUS

CLINICAL ENTITIES—GENERAL PHYSIOLOGICAL CONDITIONS

Biological and Clinical Study of a Synthetic Heparin: Dextran Sulfate (Etude biologique et clinique d'un héparinique de synthèse: le sulfate de dextrane). E. DONZELOT, H. KAUFMANN, and G. DAUZIER. *Sem. hôp. Paris*, 1955, 31: 1475.

ALTHOUGH SEVERAL SULFUR COMPOUNDS containing polysaccharides have anticoagulant properties, they are too toxic for clinical use. However, the sulfate of dextran, a new compound, is well tolerated and in some instances is superior to heparin. It can be used intravenously or intramuscularly. This compound was discovered in 1945, and was produced by treating a dry pulverized dextran with a mixture of chlorosulfonic acid and pyridine. The compound was isolated as the sodium salt; it has a formula similar to that of heparin and the glucosamines.

In vivo studies have shown that dextran sulfate does not cause the precipitation of fibrinogen or the agglutination of platelets. Its action is more antiprothrombic and antithrombic as compared to heparin. After an intravenous injection, the maximum anticoagulant activity is reached in a half hour and lasts 5 to 7 hours. There is prolongation of the coagulation time and the prothrombin time. After several days of treatment a prolongation of the effect is noted so that each injection has an effect for 2 to 3 days. Hemorrhagic complications are rare and only ecchymoses have been noted except in one case with severe hemorrhage. The action of dextran sulfate can be arrested to some degree with protamine, but in the rare case of hemorrhage blood transfusion is suggested.

The sulfate of dextran clears the blood of lipids and increases lipid mobility, as demonstrated by electrophoresis.

The authors use a solution of dextran sulfate equivalent to a heparin solution of 1,000 units per cubic centimeter. However, since their actions are somewhat different this is a gross comparison. The dextran compound has a stronger anticoagulant action than heparin.When used intensively over a short term the dosage is 2.5 c.c. given intravenously 3 times the first day, 2 the second, and then once a day or every other day thereafter. Since the effect of the drug is progressively prolonged, the dosage may have to be more widely spaced. For prolonged therapy 2 c.c. twice weekly are sufficient.

Treatment is followed by determination of coagulation and prothrombin times every other day during intensive therapy and every week or two of prolonged treatment. The blood urea levels and urinary sediment should also be checked.

Complications have been minimal and include mild, transient vasomotor disturbances, urticaria, mild diarrhea, marked hemorrhage in one debilitated patient, transient azotemia in another patient, and transient alopecia in 6 patients.

The drug was used in 60 patients and the authors feel that the over-all results were better than with heparin or heparin and dicumarol. Amelioration of the various disease processes was more rapid, and satisfactory results were obtained in heparin-resistant cases. The treated cases included thrombophlebitis, neoplastic (heparin resistant) phlebitis, and periphlebitis. In arterial occlusive diseases the pain relief and increased warmth were remarkable. This was true also in coronary artery disease. Good results were obtained in preventing thromboembolic complications of myocardial infarction. Improvement was also noted in patients with the postphlebitic syndrome.

—*Victor M. Bernhard, M.D.*

Pseudosyringomyelial Lesions of the Lower Extremities; Interpretation and Classification (Acropathies pseudosyringomyéliques des membres inférieurs; essai d'interprétation nosographique). YVES BUREAU and HENRI BARRIERE. *Sem. hôp. Paris*, 1955, 31: 1419.

THE AUTHORS present 9 cases of a unique disease entity. This disease is characterized by the presence of indolent perforating ulcers usually on the plantar surface of the forefoot, the toes, the external border of the foot, or on the heel. These lesions are confined to the lower extremities and are often bilateral. Due to underlying bone resorption, the foot becomes shortened, thick, and wide, which in association with a hard edema causes a cubelike deformity. Associated lesions include amyotrophia of the leg, trophic changes in the skin, pigmentation, thickening and irregularity of the nails, and increased sweating.

No subjective sensory changes are noted. However, sensory examination reveals loss of thermal sensation with only partial loss of pain. The ulcers are completely painless. Touch is nearly normal and deep sensation is intact. The sensory changes are bilaterally symmetrical and have a socklike distribution. The ankle reflex is often abolished whereas the patellar reflex remains.

Bone lesions develop first at the site of ulceration and parallel the extent of the disease. Arthritic changes occur at the interphalangeal joints and the metatarsophalangeal joints. These are accompanied by bone resorption and luxation of the joints. Lesions may extend beyond the areas of ulceration as the disease progresses so that eventually all of the bones of the foot become involved.

No motor disturbances, inco-ordination, or loss of bladder or bowel control are noted. Oscillometric studies are normal. Blood sugar and glucose tolerances are normal.

The disease is seen only in males in an age range from 30 to 52 years. There is no familial factor; however, geographic distribution may be significant since all of the patients lived in similar areas.

All of the patients described were alcoholics with poor dietary history and impaired nutrition. Liver disease was demonstrated by clinical examination and abnormal liver function tests. The patients were usu-

ally poor laborers or farmers. The meager nutrition and altered metabolism seen in these patients seem to be major factors underlying the trophic changes in this disease.

Local factors, such as poor foot hygiene, repeated foot trauma, and frostbite, also appeared to be of major etiologic significance.

The duration of the disease is a matter of months and years. Acute infection may complicate the problem and may result in the sequestration of bone. Functional prognosis is good even in the most severe cases since the patients can continue to walk on the diseased limbs, and amputation has never been necessary.

This syndrome does not completely fit the picture of other similar entities, such as syringomyelia or leprosy, and the authors consider it a separate entity.

The lumbar sympathetic ganglia were studied in 3 of these patients who underwent sympathectomy. Interstitial fibrosis, hyperemia, and subacute inflammation were noted. These suggest a reflex sympathetic irritation as the underlying factor in the disease process.

Treatment includes sympathectomy after paravertebral block has demonstrated improvement. Penicillin, local care, and general supportive measures to improve the liver function and metabolism contribute to the healing of the lesions.

—Victor M. Bernhard, M.D.

Dermoid Cysts. BENTLEY P. COLCOCK, ROBERT E. SASS, and LEONARD STAUDINGER. *N. England J. M.*, 1955, 252: 373.

THE AUTHORS present their findings in the treatment of dermoid cysts during the period between 1930 and 1952 at the Lahey Clinic, Boston. The cysts are divided into three types: (a) congenital dermoid cysts, (b) congenital inclusion dermoids, and (c) acquired implantation dermoids.

The results of the treatment and the findings in each group are discussed and presented in a statistical and narrative fashion. The complications such as torsion, perforation, and infection are discussed and the marked peritoneal reaction to intraperitoneal spill of the material from within the dermoid is emphasized. No instance of malignant degeneration was found among the 146 cases discussed.

—Harold M. Unger, M.D.

Foreign Body Granulomas and Sarcoidosis; a Clinical and Histopathologic Study. SVEN LÖFGREN, BJÖRN SNELLMAN, and HANS NORDENSTAM. *Acta chir. scand.*, 1955, 108: 405.

THE PURPOSE of the present study was to direct attention to the connection between cutaneous foreign-body granulomas and sarcoidosis. Cutaneous sarcoids have been observed by others in old scars. Foreign-body granulomas have been reported in the presence of pulmonary sarcoidosis.

The authors carefully examined the skin of 400 patients with pulmonary sarcoidosis. Cutaneous scars were noted in 17 patients. Conversely, 6 patients had old operation scars which led to a diagnosis of pulmonary sarcoidosis. The total number of granulomas examined was 25, cutaneous in 21 cases and subcutaneous in 4. All patients in the series presented the clinical picture of sarcoidosis. The majority of the patients were females, and 14 of the patients were between 30 and 40 years of age. The diagnosis was corroborated by histopathologic examination. The interval between the time of injury and the onset of granuloma was from 10 to 20 years, with exception of those cases which developed after biopsy for sarcoidosis. In the latter the interval did not exceed 3 years.

The histopathologic picture was that of a foreign-body granuloma with marked sarcoid tissue reaction. Crystals suggestive of talc were demonstrated in all postoperative scar granulomas. Foreign bodies were also demonstrated in the scar granulomas resulting from trauma, with one exception. Some of these resembled quartz. Proof of the type of foreign body was difficult to secure, but quartz was demonstrated in 4 cases and talc in 2.

The relationship between certain foreign body granulomas and sarcoidosis is of considerable practical importance. When such granulomas develop after many years, roentgen films of the lungs should be taken and studied in a search for sarcoid disease. If epithelioid-cell formation is prominent in the histopathologic appearance where foreign bodies are scarce, sarcoidosis is to be suspected. The etiologic factors are discussed and the clinical and histologic picture is well illustrated. *—Donald C. Geist, M.D.*

Subcutaneous Cicatricial Sarcoid Following Operation for Hyperthyroidism. SVEN RUNE JOHNSON and RAGNAR ROMANUS. *Acta chir. scand.*, 1955, 108: 419.

THE AUTHORS present 3 cases of cicatricial sarcoid which followed operation for hyperthyroidism. The operative scar was the seat of the sarcoid in all 3 patients. The diagnosis was made on the basis of the clinical findings and was corroborated by pathologic examination.

Two of the patients were females, 31 and 47 years of age, and the third patient was a male, age 47. The lesion lay in or beneath the scar in all 3 patients. It appeared 8 to 12 years after the operative procedure. All patients presented typical pulmonary roentgenologic findings. The lesion was removed in 1 case and a biopsy was done in 2 cases. The remaining lesion disappeared following biopsy in each of the latter 2 cases. In 2 of the patients the lesion extended into the subcutaneous tissue beyond the limits of the scar.

The diagnosis may be made on the clinical, roentgenologic, and histologic findings. The disease is a local manifestation in a longstanding scar, with generalization of the sarcoidosis. The prognosis is usually good. The chief point in diagnosis is its differentiation from foreign body granuloma. Keloid should also be taken into account.

The authors believe that sarcoidosis should be considered in the presence of any infiltration in or beneath an old scar. *—Donald C. Geist, M.D.*

Subcutaneous Cords on the Trunk. GÖSTA JÖNSSON, FOLKE LINELL, and PHILIP SANDBLOM. *Acta chir. scand.*, 1955, 108: 351.

A PECULIAR CONDITION characterized by thin subcutaneous cords in the thoracoabdominal wall has been described by various authors whose contri-

butions have appeared in the French literature during the past 30 years. The symptoms are those of pain in the cord, or a feeling of stretching during muscular action.

Eight cases of the condition, with a careful study of the pathologic findings, are presented. In all cases the cord was excised in toto with complete relief of the symptoms.

Histologically, the lesion consists of a cordlike structure of fibrous tissue with mature fibroblasts. In one case the cord gradually merged into a vessel which most closely resembled a lymphatic vessel, and suggested to the authors a fibrosing lymphangitis.

In all of the cases the process has been self-limited, the cord eventually disappearing. Excision (done here for diagnostic purposes) is not indicated, except for very severe symptoms. It is believed that the lesion should be removed, however, if it is near the female breast and the patient suspects malignancy.

—Harold M. Unger, M.D.

Specificity or Nonspecificity in the Pathogenesis of Cancer (Spezifitaet oder Unspezifitaet im Krebsgeschehen?) HORST JAEGER. *Arch. Geschwulstforsch.*, 1954, 7: 340.

The first part of this article is devoted to a detailed discussion of the theories of a group of German investigators (Rudolf Koch, Joseph Koch, and von Brehmer) who believe that cancer is caused by specific, very small viruslike intracellular organisms. According to one of these men, these viruses represent the earliest stages in the development of a specific protozoan belonging to the class of Flagellata.

The author of the present article rejects these theories. It has been well known for a long time that a great number of parasites, bacteria, and viruses may play a role in the pathogenesis of malignant tumors: viz., Schistosoma haematobium in bladder carcinoma, echinococcus and Opisthorchis felineus in liver carcinoma, Spirochaeta pallida in cancer of the tongue and lips; however, the irritation by these and other organisms and viruses is nonspecific.

Among the numerous mechanical, physical, and chemical factors which may play a role in carcinogenesis, the author discusses especially the tar derivatives, a great number of which produce transplantable malignant tumors even in minute amounts in animal experiments. One investigator showed that 0.00004 mgm. of dibenzanthrazene produced transplantable sarcoma in mice.

In the last part of the article the author presents a theory on carcinogenesis. In experiments with tar derivatives, other investigators have shown that these lipoid-soluble substances accumulate in the cell protoplasm, which is rich in lipoids, without entering the nucleus. The author assumes that these factors originate in irreversible mutation of the cell which thus becomes the primary cancer cell. This "defect mutation" takes place in the cytoplasm rather than in the nucleus.

The function of different parts of the cell is discussed, and it is hypothesized that the cancerogenic noxae involve primarily the mitochondria and the microsomes, and secondarily the centrosphere.

—Werner M. Solmitz, M.D.

Primary Malignant Tumors of the Hand. ROBERT H. CLIFFORD and ALEX P. KELLY, JR. *Plastic & Reconstr. Surg.*, 1955, 15: 227.

MALIGNANT TUMORS of the hand were studied in persons registered at the Henry Ford Hospital and its clinics. In this series of 757,827 patients there were 9,741 with verified malignant tumors, an incidence of 1.3 per cent. Sixty-three patients with primary malignant tumors of the hand were registered, an incidence of 0.008 per cent. Malignant tumors of the hand represented 0.62 per cent of all cancers.

HAND TO BODY TUMOR RELATIONSHIPS

	Body as a whole	*Hand (per cent)*
Basal cell carcinoma	329	5 (1.5)
Squamous cell carcinoma of skin	312	47 (15.1)
Malignant bone tumors	144	2 (1.2)
Melanoma	126	4 (3.2)
Sarcoma	140	5 (3.6)

There were 5 basal cell carcinomas of the hand. The ratio of squamous cell carcinomas to basal cell carcinomas was 9 to 1. All basal cell lesions were cured by a single excision. Four patients had malignant melanomas on the hand and fingers; the group contained 2 subungual melanomas, a melanosarcoma arising in a blue nevus, and a melanoma of the dorsum of the hand. The last mentioned patient with melanoma was admitted in extremis. The patient with melanosarcoma is living without evidence of disease 8 years after wide local incision. The 2 patients with melanotic whitlow were treated successfully by digital amputation. Subungual melanoma carries a better prognosis than other melanomas, probably because the surgeon is not loath to suggest nor the patient to accept a digital amputation.

There were 2 malignant tumors of the bones of the hand. Of these, one was an osteogenic sarcoma of the fourth metacarpal. The patient survived for 7 years without evidence of disease following an amputation of the fourth and fifth rays. The other, a Ewing's endothelioma of the proximal phalanx of the middle finger, had widespread metastases which were found at autopsy 5 months following amputation of the involved ray.

There were 5 sarcomas involving the hand. One was a mesotheliosarcoma, and 4 were fibrosarcomas. The mesotheliosarcoma has shown no evidence of recurrence 9 years after local excision. Three patients with fibrosarcomas are living and free of disease—2 after wide excision 20 and 26 years ago, and 1 after amputation of the hand 11 years ago. One patient died 1 year after amputation of the hand for an extensive lesion of the thenar eminence. In view of the results obtained with relatively conservative procedures, the authors find it difficult to accept the suggestions of some that arm or shoulder girdle amputations are the most suitable form of treatment.

The largest group of tumors consisted of squamous cell carcinomas, 47 in number. The patients were of advanced age—averaging 64.9 years. These lesions have a well known propensity to develop in scars or in pre-existing congenital or acquired neoplasms; in 55.3 per cent of the cases in this series the carcinoma was preceded by such lesions. The results were eval-

uated on the basis of survival for 3 years without evidence of disease; they were not evaluated on a 5-year basis because many of the patients in this advanced age group die of intercurrent disease. A 5-year survival rate would present a picture that does not truly represent the curability of the disease.

In the authors' opinion, treatment of the local lesion is purely surgical. Local excision is adequate for small lesions. If the lesion is fixed to underlying structures, partial amputation of the hand or finger may be necessary. Radiation therapy is generally considered unsuitable. Treatment of nodal metastases, when present, should consist of radical dissection.

Radical dissections of the axilla are not undertaken lightly in persons of this age group, and a precise method of evaluating the cases of patients in need of such surgery would be welcomed. Johnson and Ackerman's finding that lesions which were above the sweat gland level did not metastasize, in their experience, offers promise of an accurate method of appraisal of these cases. In the authors' cases showing metastases, the observation is valid. If this finding proves valid in a large number of cases, it would indicate that a considerable advance has been made in the therapy of these lesions.

—*Edmund R. Donoghue, M.D.*